ANNUAL REPORT OF THE BOARD OF REGENTS OF

THE SMITHSONIAN INSTITUTION

SHOWING THE

OPERATIONS, EXPENDITURES, AND CONDITION OF THE INSTITUTION FOR THE YEAR ENDED JUNE 30

1942

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LETTER OF TRANSMITTAL

SMITHSONIAN INSTITUTION,
Washington, December 10, 1942.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and conditions of the Smithsonian Institution for the year ended June 30, 1942. I have the honor to be,

Very respectfully, your obedient servant,

C. G. ABBOT, *Secretary.*

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THE SMITHSONIAN INSTITUTION

June 30, 1942

Presiding officer ex officio.—FRANKLIN D. ROOSEVELT, President of the United States.

Chancellor.—HARLAN F. STONE, Chief Justice of the United States.

Members of the Institution:

FRANKLIN D. ROOSEVELT, President of the United States.
HENRY A. WALLACE, Vice President of the United States.
HARLAN F. STONE, Chief Justice of the United States.
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HENRY MORGENTHAU, Jr., Secretary of the Treasury.
HENRY L. STIMSON, Secretary of War.
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FRANK C. WALKER, Postmaster General.
FRANK KNOX, Secretary of the Navy.
HAROLD L. ICKES, Secretary of the Interior.
CLAUDE R. WICKARD, Secretary of Agriculture.
JESSE H. JONES, Secretary of Commerce.
FRANCES PERKINS, Secretary of Labor.

Regents of the Institution:

HARLAN F. STONE, Chief Justice of the United States, Chancellor.
HENRY A. WALLACE, Vice President of the United States.
CHARLES L. MCNARY, Member of the Senate.
ALBEN W. BARKLEY, Member of the Senate.
BENNETT CHAMP CLARK, Member of the Senate.
CLARENCE CANNON, Member of the House of Representatives.
WILLIAM P. COLE, Jr., Member of the House of Representatives.
FOSTER STEARNS, Member of the House of Representatives.
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ROLAND S. MORRIS, citizen of Pennsylvania.
HARVEY N. DAVIS, citizen of New Jersey.
ARTHUR H. COMPTON, citizen of Illinois.
VANNEVAR BUSH, citizen of Washington, D. C.
FREDERIC C. WALCOTT, citizen of Connecticut.

Executive Committee.—FREDERIC A. DELANO, VANNEVAR BUSH, CLARENCE CANNON.

Secretary.—CHARLES G. ABBOT.

Assistant Secretary.—ALEXANDER WETMORE.

Administrative assistant to the Secretary.—HARRY W. DORSEY.

Treasurer.—NICHOLAS W. DORSEY.

Chief, editorial division.—WEBSTER P. TRUE.

Librarian.—LEILA F. CLARK.

Personnel officer.—HELEN A. OLMSTED.

Property clerk.—JAMES H. HILL.

UNITED STATES NATIONAL MUSEUM

Keeper ex officio.—CHARLES G. ABBOT.
Assistant Secretary (in charge).—ALEXANDER WETMORE.
Associate Director.—JOHN E. GRAF.

SCIENTIFIC STAFF

DEPARTMENT OF ANTHROPOLOGY:

Frank M. Setzler, head curator; A. J. Andrews, chief preparator.

Division of Ethnology: H. W. Krieger, curator; J. E. Weckler, Jr., associate curator; Arthur P. Rice, collaborator.

Section of Ceramics: Samuel W. Woodhouse, collaborator.

Division of Archeology: Neil M. Judd, curator; Waldo R. Wedel, associate curator; R. G. Paine, senior scientific aid; J. Townsend Russell, honorary assistant curator of Old World archeology.

Division of Physical Anthropology: T. Dale Stewart, curator; M. T. Newman, associate curator.

Collaborator in anthropology: George Grant MacCurdy. Associate in anthropology: Aleš Hrdlička.

DEPARTMENT OF BIOLOGY:

Leonhard Stejneger, head curator; W. L. Brown, chief taxidermist; Aime M. Awl, illustrator.

Division of Mammals: Remington Kellogg, curator; D. H. Johnson, associate curator; H. Harold Shamel, senior scientific aid; A. Brazier Howell, collaborator; Gerrit S. Miller, Jr., associate.

Division of Birds: Herbert Friedmann, curator; H. G. Deignan, associate curator; S. Dillon Ripley, II, assistant curator; Alexander Wetmore, custodian of alcoholic and skeleton collections; Arthur C. Bent, collaborator.

Division of Reptiles and Batrachians: Leonhard Stejneger, curator; Doris M. Cochran, associate curator.

Division of Fishes: Leonard P. Schultz, curator; E. D. Reid, senior scientific aid.

Division of Insects: L. O. Howard, honorary curator; Edward A. Chapin, curator; R. E. Blackwelder, associate curator.

Section of Hymenoptera: S. A. Rohwer, custodian; W. M. Mann, assistant custodian; Robert A. Cushman, assistant custodian.

Section of Myriapoda: O. F. Cook, custodian.

Section of Diptera: Charles T. Greene, assistant custodian.

Section of Coleoptera: L. L. Buchanan, specialist for Casey collection.

Section of Lepidoptera: J. T. Barnes, collaborator.

Section of Forest Tree Beetles: A. D. Hopkins, custodian.

Division of Marine Invertebrates: Waldo L. Schmitt, curator; C. R. Shoemaker, associate curator; James O. Maloney, aid; Mrs. Harriet Richardson Searle, collaborator; Max M. Ellis, collaborator; J. Percy Moore, collaborator; Joseph A. Cushman, collaborator in Foraminifera.

Division of Mollusks: Paul Bartsch, curator; Harald A. Rehder, associate curator; Joseph P. E. Morrison, senior scientific aid.

Section of Helminthological Collections: Benjamin Schwartz, collaborator.

Division of Echinoderms: Austin H. Clark, curator.

DEPARTMENT OF BIOLOGY—Continued.

Division of Plants (National Herbarium): W. R. Maxon, curator; Ellsworth P. Killip, associate curator; Emery C. Leonard, assistant curator; Conrad V. Morton, assistant curator; Egbert H. Walker, assistant curator; John A. Stevenson, custodian of C. G. Lloyd mycological collection.

Section of Grasses: Agnes Chase, custodian.

Section of Cryptogamic Collections: O. F. Cook, assistant curator.

Section of Higher Algae: W. T. Swingle, custodian.

Section of Lower Fungi: D. G. Fairchild, custodian.

Section of Diatoms: Paul S. Conger, custodian.

Associates in Zoology: Mary J. Rathbun, Theodore S. Palmer, William B. Marshall, A. G. Böving.

Associate in Marine Sediments: T. Wayland Vaughan.

Associate in Botany: Henri Pittier.

Collaborator in Zoology: Robert Sterling Clark.

Collaborators in Biology: A. K. Fisher, David C. Graham.

DEPARTMENT OF GEOLOGY:

R. S. Bassler, head curator; Jessie G. Beach, aid.

Division of Mineralogy and Petrology: W. F. Foshag, curator; E. P. Henderson, associate curator; B. O. Reberholt, senior scientific aid; Frank L. Hess, custodian of rare metals and rare earths.

Division of Invertebrate Paleontology and Paleobotany: Charles E. Resser, curator; Gustav A. Cooper associate curator; Marion F. Willoughby, senior scientific aid.

Section of Invertebrate Paleontology: T. W. Stanton, custodian of Mesozoic collection; Paul Bartsch, curator of Cenozoic collection.

Division of Vertebrate Paleontology: Charles W. Gilmore, curator; C. Lewis Gazin, associate curator; Norman H. Boss, chief preparator.

Associates in Mineralogy: W. T. Schaller, S. H. Perry.

Associate in Paleontology: E. O. Ulrich.

Associate in Petrology: Whitman Cross.

DEPARTMENT OF ENGINEERING AND INDUSTRIES:

Carl W. Mitman, head curator.

Division of Engineering: Frank A. Taylor, curator.

Section of Transportation and Civil Engineering: Frank A. Taylor, in charge.

Section of Aeronautics: Paul E. Garber, associate curator.

Section of Mechanical Engineering: Frank A. Taylor, in charge.

Section of Electrical Engineering and Communications: Frank A. Taylor, in charge.

Section of Mining and Metallurgical Engineering: Carl W. Mitman, in charge.

Section of Physical Sciences and Measurement: Frank A. Taylor, in charge.

Section of Tools: Frank A. Taylor, in charge.

Division of Crafts and Industries: Frederick L. Lewton, curator; Elizabeth W. Rosson, senior scientific aid.

Section of Textiles: Frederick L. Lewton, in charge.

Section of Woods and Wood Technology: William N. Watkins, associate curator.

Section of Chemical Industries: Wallace E. Duncan, assistant curator.

Section of Agricultural Industries: Frederick L. Lewton, in charge.

DEPARTMENT OF ENGINEERING AND INDUSTRIES—Continued.

Division of Medicine and Public Health: Charles Whitebread, associate curator.

Division of Graphic Arts: R. P. Tolman, curator.

Section of Photography: A. J. Olmsted, associate curator.

DIVISION OF HISTORY: T. T. Belote, curator; Charles Carey, assistant curator; Catherine L. Manning, philatelist.

ADMINISTRATIVE STAFF

Chief of correspondence and documents.—H. S. BRYANT.
Assistant chief of correspondence and documents.—L. E. COMMERFORD.
Superintendent of buildings and labor.—R. H. TREMBLY.
Assistant superintendent of buildings and labor.—CHARLES C. SINCLAIR.
Editor.—PAUL H. OEHSER.
Accountant and auditor.—N. W. DORSEY.
Photographer.—A. J. OLMSTED.
Property clerk.—LAWRENCE L. OLIVER.
Assistant librarian.—ELISABETH P. HOBBS.

NATIONAL GALLERY OF ART

Trustees:

THE CHIEF JUSTICE OF THE UNITED STATES, *Chairman.*
THE SECRETARY OF STATE.
THE SECRETARY OF THE TREASURY.
THE SECRETARY OF THE SMITHSONIAN INSTITUTION.
DAVID K. E. BRUCE.
FERDINAND LAMMOT BELIN.
DUNCAN PHILLIPS.
SAMUEL H. KRESS.
JOSEPH E. WIDENER.

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Assistant Director.—MACGILL JAMES.
Administrator.—H. A. MCBRIDE.
Chief Curator.—JOHN WALKER.

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FREER GALLERY OF ART

Director.—JOHN ELLERTON LODGE.
Assistant Director.—GRACE DUNHAM GUEST.
Associate in research.—ARCHIBALD G. WENLEY.
Superintendent.—W. N. RAWLEY.

BUREAU OF AMERICAN ETHNOLOGY

Chief.—Matthew W. Stirling.
Senior ethnologists.—H. B. Collins, Jr., John P. Harrington, John R. Swanton.
Senior archeologist.—Frank H. H. Roberts, Jr.
Senior anthropologist.—Julian H. Steward.
Associate anthropologist.—W. N. Fenton.
Editor.—M. Helen Palmer.
Librarian.—Miriam B. Ketchum.
Illustrator.—Edwin G. Cassedy.

INTERNATIONAL EXCHANGE SERVICE

Secretary (in charge).—Charles G. Abbot.

NATIONAL ZOOLOGICAL PARK

Director.—William M. Mann.
Assistant Director.—Ernest P. Walker.

ASTROPHYSICAL OBSERVATORY

Director.—Charles G. Abbot.

Division of Astrophysical Research: Loyal B. Aldrich, assistant director; William H. Hoover, senior astrophysicist.

Division of Radiation and Organisms: Earl S. Johnston, assistant director; Edward D. McAlister, senior physicist; Leland B. Clark, senior mechanical engineer; Robert L. Weintraub, junior biochemist.

REPORT OF THE SECRETARY OF THE SMITHSONIAN INSTITUTION

C. G. ABBOT

FOR THE YEAR ENDED JUNE 30, 1942

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to submit herewith my report showing the activities and condition of the Smithsonian Institution and the Government bureaus under its administrative charge during the fiscal year ended June 30, 1942. The first 23 pages contain a summary account of the affairs of the Institution, and appendixes 1 to 11 give more detailed reports of the operations of the National Museum, the National Gallery of Art, the National Collection of Fine Arts, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, which now includes the Division of Radiation and Organisms, the Smithsonian library, and of the publications issued under the direction of the Institution. On page 99 is the financial report of the executive committee of the Board of Regents.

THE SMITHSONIAN AND THE WAR

In my last report I stated that in the fiscal year 1941 the Smithsonian had been assigned several problems connected with national defense and stood ready to devote all its resources to such work when called upon. After Pearl Harbor, calls upon the Institution for special information relating to the war increased rapidly, and early in 1942 I appointed a War Committee for the purpose of exploiting every facility of the Institution in aiding the war effort. Such a highly specialized organization as the Smithsonian obviously can only undertake those things which its staff is trained and equipped to do, but the exploratory investigations of the War Committee revealed a surprisingly wide range of activities in which the Institution could engage that are directly or indirectly of real service in the war effort.

For some organizations whose normal activities are in fields directly applicable to war work, such for example as those concerned with strategic materials or those with large physical laboratories, the problem of going over to a war footing is solved for them. For such

establishments as the Smithsonian, with its normal functions of research, chiefly in the natural sciences, publication of results of scientific researches, museum and art gallery exhibition, and international exchange of literature, the problem is not so simple. Every member of the staff desires earnestly to do his utmost to aid in the war effort, but in many instances, as the following summary of Smithsonian war activities shows, the only possible way of putting the desire into effect is connected only indirectly with war work. Nevertheless, work such as that which the Smithsonian is qualified to perform will, I believe, be seen to fill a definite place in the Nation's all-out war effort.

The membership of the War Committee is as follows: C. W. Mitman, engineer, chairman; L. B. Aldrich, physicist; W. N. Fenton, ethnologist; Herbert Friedmann, biologist; and W. P. True, chief, editorial division. For several weeks the committee met every day in the effort to speed up the diversion of as much as possible of the Institution's work into war channels. Several questionnaires were sent to the staff asking for suggestions and detailed information as to the qualifications, travel, and special knowledge of each member. With these data before them, the committee began to make recommendations, most of which I approved and put into effect. Those projects which had been initiated up to June 30, 1942, are as follows:

1. The Institution has prepared a detailed roster of the scientific staff totaling nearly 100 scientists, listing their geographic and specialized knowledge. Some of this knowledge has proved to be readily available nowhere else, and the roster has been extensively used in connection with inquiries from war agencies.

2. A record of requests from war agencies for specific information from individual staff members shows a total of 460 such received since Pearl Harbor. Fifty percent came directly from the War and Navy Departments, the rest from 25 different other war agencies. In short, the Smithsonian is serving as an important source of technical and geographic information.

3. The Smithsonian, together with the National Research Council, the American Council of Learned Societies, and the Social Science Research Council, has actively participated in the setting up of the Ethnogeographic Board. The Institution furnishes financial support and facilities, and serves as the headquarters for the Board, whose purpose is to provide a central clearinghouse for information to Army and Navy Intelligence and other war agencies in the fields of geography, languages, and social sciences. Dr. William Duncan Strong, formerly of the Bureau of American Ethnology and now a member of the staff of Columbia University, was appointed director of the Board. Members of the staff of the Institution are cooperating closely in the work.

4. The Smithsonian has thousands of published and unpublished photographs taken by its scientists in all parts of the world, including many out-of-the-way places not commonly photographed. An index is being compiled of the published material, and members of the staff have put their photographic files in shape for ready consultation by war agencies. Many of its photographs have already been so consulted.

5. In the very important field of Latin American cooperation, the Institution has undertaken two large-scale scientific projects. One is a Handbook of the Indians of South America, under the editorship of Dr. Julian H. Steward, of the Bureau of American Ethnology. The various articles will be contributed by both Latin American and North American anthropologists. This will be published under the auspices of the Institution. The other is a list of the insects of South and Central America, a much-needed tool for all future entomological work in those areas. The completed list, which is estimated to make more than a thousand pages of print, will also appear as a Smithsonian publication.

6. Approximately 10 percent of the scientific staff are engaged in full-time war projects assigned to them by the Army, Navy, or other war agencies. This work is being done either at the Institution or through transfer of personnel to the agency requesting the work. All the rest of the staff members devote a portion of their time to work related directly or indirectly to the war, the actual amount of time depending on the extent to which their special knowledge is needed by war agencies.

7. In the line of its normal function of diffusion of knowledge, the Institution has initiated several wartime projects. A new series of pamphlets entitled "War Background Studies" and a series of news releases headed "War Background Data" have as their purpose the increasing of popular understanding of the various regions and peoples involved in the world conflict. In the Smithsonian's radio program, "The World Is Yours," four broadcasts were given on a Nationwide network comprising a series on the peoples of the United Nations. Several special war exhibits were shown in the Smithsonian and Museum buildings and others are definitely planned. A series of special lectures on war topics has been arranged, and at the close of the fiscal year its beginning awaited only the installation of new projection equipment in the Museum auditorium. A set of six postcards illustrating Museum exhibits was printed for free distribution to service men; in conjunction with these, writing counters and a mail box were installed at the entrance to the Arts and Industries Building where men in uniform write and mail the cards. Thousands of sets had been given out at the close of the year, and this service

seems to be much appreciated. All the Museum buildings are now open all day Sunday for the benefit of service men and war workers.

8. The War Committee and officials of the Institution have established definite contacts with the War and Navy Departments and other war agencies; through these contacts continual efforts are being made to channel more war-time researches and other suitable activities to the Institution.

The War Committee will continue to function for the duration.

ENDING OF WRIGHT-SMITHSONIAN CONTROVERSY

By anticipation, I report with great relief and peculiar satisfaction the ending of the long controversy between Dr. Orville Wright and the Smithsonian Institution. Negotiations, in which Colonel Lindbergh and others had taken part, had proceeded intermittently between the Secretary and Dr. Wright since 1928. Since June 1942, in part with the mediation of Fred C. Kelly, an active interchange of communications has gone on. It resulted in a statement acceptable to Dr. Wright which was published by the Institution in its Miscellaneous Collections, volume 103, No. 8, October 24, 1942. This statement, which speaks for itself, it is intended to republish as the first article of the Appendix to the Smithsonian Report for 1942. In his letter of October 17, 1942, Dr. Wright says: "I hope the relations between the Institution and myself may again be as amicable as they were in Dr. Langley's administration."

SUMMARY OF THE YEAR'S ACTIVITIES OF THE BRANCHES OF THE INSTITUTION

National Museum.—Accessions for the year totaled 284,582 specimens, bringing the number of catalog entries in all departments to 17,578,240. Among the outstanding accessions may be mentioned the following: In anthropology, 200 artifacts from the old Indian village site of Potawomeke, Stafford County, Va.; cult objects from voodoo shrines in Haiti, and weapons of the Moro of Mindanao, P. I.; in biology, 30 Antarctic seals, 54 Manchurian mammals, 1,845 birds from Colombia collected by Dr. Alexander Wetmore and M. A. Carriker, Jr., 14,219 fishes from the area between Peru and Alaska received from the United States Fish and Wildlife Service, a collection of 25,000 specimens of Hemiptera received from W. L. McAtee, 7,600 specimens, mostly termites, collected in Jamaica by Dr. Edward A. Chapin, and 2,169 specimens of plants of Colombia received in continuation of exchanges from the Instituto de Ciencias Naturales, Bogotá, Colombia; in geology, a large aquamarine from Agua Preta, Minas Geraes, Brazil, purchased from the Roebling fund, a 2,690-gram specimen of the Rose City, Mich., stony meteorite presented by Dr. Stuart H. Perry, 4 tons of limestone blocks of beautifully preserved silicified Permian fossils collected in Texas by Dr. G. A.

Cooper, and 8,000 Cambrian and Devonian fossils collected by Dr. C. E. Resser in Montana, Utah, and the Canadian Rockies; in engineering and industries, a number of models of historic aircraft, an example of the Allison liquid-cooled aircraft engine, type V-1710-C, a jeep lent by the War Department, the first Emerson iron lung completed in 1931, and a collection of 183 Currier and Ives prints given by Miss Adele S. Colgate. Although field expeditions were greatly curtailed because of war conditions, those to which the Museum was previously committed were carried through with valuable results in specimens and new information. Visitors to the Museum numbered 2,042,817. Although this was nearly half a million less than in the previous year, nevertheless the decrease was less than had been anticipated in view of restrictions on automobile travel. The Museum issued 44 publications and distributed 82,545 copies during the year. Fifteen special exhibits were held in the Museum under the auspices of various scientific and other groups. Among numerous changes in the staff may be mentioned the retirement, after nearly 39 years of service, of Dr. Aleš Hrdlička as curator of the division of physical anthropology; Dr. T. Dale Stewart, associate curator of the division, was promoted to the curatorship to succeed him.

National Gallery of Art—The total attendance at the Gallery for the first full year of its operation was 2,005,328, a daily average of over 5,500 visitors. In June the Gallery began a series of Sunday evening openings for the benefit of service men and war workers. Concerts and special lectures featured these Sunday openings, which proved so successful that it was decided to continue them indefinitely. Publications available to the public are a general information booklet, a catalog of the paintings and sculpture, a book of illustrations of all the works of art in the Gallery, color reproductions, and postcards. Since Pearl Harbor the Gallery has been blacked out nightly, and frequent air-raid drills have been held. A limited number of the most fragile and irreplaceable works of art have been removed to a place of greater safety, but it is the expressed belief of the Board of Trustees that the Gallery has a duty to the public and an obligation as a source of recreation and education to continue its activities and even increase them in war time. Gifts of prints, paintings, and sculpture were accepted from eight different donors, and a number of important loans were received. Seven special exhibitions were held at the Gallery, including one of drawings of war-time London, another of the art of Australia, and one of 11 portrait busts of the Presidents of the Republics of South America, by Jo Davidson. The Gallery's educational program included Gallery tours of the collection conducted twice daily; a series of 34 special lectures, one given each Saturday afternoon from October to April, and Gallery talks and other lectures dealing with a

specific school or specific works of art. Beginning in December, special tours for members of the armed forces were arranged for Saturday afternoons.

National Collection of Fine Arts.—The necessary plans were made during the year for the protection and evacuation of works of art in the National Collection. Four oil paintings and a number of other works of art were accepted for the collection by the Smithsonian Art Commission. Three miniatures were acquired through the Catherine Walden Myer fund. Eight special exhibitions were held as follows: Miniatures lent by Count and Countess Bohdan de Castellane; oils and water colors by Roy M. Mason, N. A.; oils, prints, and drawings by Antonio Rodriguez Luna, of Mexico; jade lent by Georges Estoppey; paintings on metal and prints by Buell Mullen; oils, water colors, and prints by members of the Landscape Club of Washington, D. C.; plaster busts by Marina Nuñez del Prado, of Bolivia; oil paintings, pencil drawings, lithographs, and water colors by Ignacio Aguirre, of Mexico.

Freer Gallery of Art.—Additions to the collections included Persian and Syrian brass; Chinese bronze; Chinese jade; Arabic manuscript; Arabic, Chinese, and Persian painting; Arabic, Mesopotamian, Persian, and Syro-Egyptian pottery. The regular work of the curatorial staff was devoted to the study and recording of these new acquisitions and other art objects already in the collection. In addition, 770 objects and 235 photographs of objects were submitted to the Director by their owners for information as to identity, provenance, quality, date, or inscriptions. Besides this usual work, the staff devoted much of its time during the winter and spring to work connected with the war. The total number of visitors to the Gallery for the year was 87,890. A number of groups were given docent service in the exhibition galleries and study rooms. Carl Whiting Bishop associate in archeology, a member of the Gallery staff since 1922, died on June 16, 1942. From 1923 to 1927, and from 1929 to 1934, Mr. Bishop was in charge of the Freer Gallery field work in China. He published numerous articles on Chinese archeology in various journals and was widely known as an authority on the earlier phases of Chinese culture.

Bureau of American Ethnology.—The time of the members of the Bureau's scientific staff has been devoted more and more to activities concerned with the war effort. Their specialized geographical, racial, and linguistic knowledge has been in constant demand by the Army, Navy, and other war agencies, and certain staff members have cooperated closely with the Ethnogeographic Board, an agency that acts as a clearinghouse for anthropological, geographical, and related information needed in the war effort. As time permitted, the Bureau continued its normal work of studying the American

Indian. M. W. Stirling, Chief of the Bureau, spent 2 months in Mexico in continuation of the Smithsonian Institution-National Geographic Society archeological project in that country. Dr. John R. Swanton continued work on a study of the language of the Timucua Indians of Florida and on the revision of a large general paper on the Indians of North America. Dr. John P. Harrington carried forward work on two problems involving linguistic studies of Aleut, the language of the islands between Asia and America, and of Athapascan, the language of the northern Rockies, of a large part of the Pacific coast, and of the southern deserts. Dr. Frank H. H. Roberts, Jr., conducted archeological excavations at a site near San Jon, N. Mex., uncovering an interesting sequence of projectile points and other artifact types and obtaining new information on aboriginal occupation of that area. Just before the close of the year Dr. Roberts went to Newcastle, Wyo., to inspect a promising archeological site. Dr. Julian H. Steward continued his work as editor of the Handbook of South American Indians, in the course of which he visited Brazil, Argentina, Paraguay, and Chile for conferences with Latin-American anthropologists. Dr. Henry B. Collins, Jr., continued the study of archeological materials from prehistoric Eskimo village sites around Bering Strait. Dr. W. N. Fenton carried on several investigations relating to the Iroquois Indians. Dr. Philip Drucker made an analysis of the pottery collections made in Mexico in 1941 by the Smithsonian Institution-National Geographic Society expedition. In continuation of the work of this expedition he went in January 1942 to a site at La Venta, in northwest Tabasco, where excavations resulted in a number of interesting discoveries. Miss Frances Densmore, a collaborator of the Bureau, recorded Omaha songs at Macy, Nebr. The Bureau published its Annual Report and three Bulletins. The library accessioned 350 items; the reclassification of the library was practically completed during the year.

International Exchanges.—The Exchange Service acts as the official United States agency for the interchange of parliamentary, governmental, and scientific publications between this country and the rest of the world. The Service handled during the year 561,151 packages of publications weighing 326,406 pounds. As would be expected, the work of the Exchange Service was greatly hampered by the war. In the Eastern Hemisphere only Great Britain and the Union of South Africa continued to receive shipments from this country. In the Western Hemisphere, where all packages are sent by mail, there was no interruption to the sending of exchanges, although censorship caused some delay. In April 1942 the sending of the Congressional Record to foreign countries through the Ex-

change Service was discontinued for the duration at the request of the Office of Censorship.

National Zoological Park.—Although war conditions reduced the number of out-of-town visitors to the Zoo, more people from nearby areas came by bus and streetcar and on foot, bringing the total attendance for the year to 2,523,300, or sightly more than the number for the previous year. A considerable proportion of the attendance was made up of men in the armed services, many of them enjoying their first oportunity of visiting a large zoo. As usual, a large number of gifts of animals came to the Park, and there were 65 mammals born, 40 birds hatched, and 2 reptiles born during the year. Deaths included a sulphur-crested cockatoo that had been in the Zoo for 52 years, and the American bald eagle "Jerry," a Zoo resident for 26 years. The epidemic of psittacosis that caused serious losses of birds and caused the closing of the bird house to the public for 3 months, as noted in last year's report, was finally subdued through the cooperation of the United States Public Health Service and the District of Columbia Health Department. Many of the poisonous reptiles have been removed from the Zoo, leaving so few that they could be quickly disposed of in an emergency. At the close of the year, the collection contained a total of 2,411 animals, representing 722 different species.

Astrophysical Observatory.—The most important event of the year was the publication of volume 6 of the Annals of the Observatory, which covers its operations from 1920 to 1939. Besides describing in detail the principal research on the variation of the sun's radiation, the volume is the culmination of several years' work devoted to revising the daily results of observation of the solar constant of radiation at the three field observing stations at Montezuma, Chile, Table Mountain, Calif., and Mount St. Katherine, Egypt, from 1923 to 1939. The values published clearly indicate the variation of the sun between extreme ranges up to about 3 percent for the period covered. The variation is shown to be composed of 14 periodicities ranging from 8 months to 273 months. Each of these periods is reflected in terrestrial temperature and precipitation as recorded by official weather services. Another important event was the incorporation as a branch of the Observatory of the Smithsonian Division of Radiation and Organisms, hitherto supported by private funds. Considerable confidential work for military purposes was done in the Observatory's instrument shop under the care of the Director. Because of the discovery that the percentage variations of the intensity of sun's rays is 6 times as great for ultraviolet rays as for the total of all wave lengths, apparatus was prepared in the instrument shop for restricting the determinations of solar variations to the spectral regions of the green, blue, violet, and ultraviolet

rays. This apparatus has been installed at all three field stations. Also prepared in the instrument shop were three copies of a sky polarization device invented by the late Prof. E. C. Pickering. It is believed that the use of this device at the observing stations will obviate the unsatisfactory results brought about by certain types of sky conditions. Solar observations on all favorable days have been continued at the three present field stations at Table Mountain, Calif., Burro Mountain, N. Mex., and Montezuma, Chile.

Division of Radiation and Organisms.—On July 1, 1941, the Division became a branch of the Astrophysical Observatory and received Congressional appropriation for the support of its researches. Members of its staff were given Civil Service status. The present research work of the Division comes under three headings: Photosynthesis, plant growth and radiation, and development of apparatus and methods. Experiments were continued on the factors that influence the change in rates of respiration in plants, which led to speculation on the possibility of the existence of a carbon dioxide reservoir connected with the cell mechanism. There is evidence also that the humidity of the air plays an important role in this gaseous exchange. The study of the relationship between light intensity and inhibition of growth of the oats mesocotyl was extended to higher intensities. Work is in progress on the isolation and separation of two pigments indicated to occur in dark-grown oat seedlings. Previous work in the Division had shown that illumination increases the rate of carbon dioxide production by etiolated barley seedlings. Apparatus was assembled and preliminary experiments were begun to study the influence of radiation on the respiration of other types of plants. (Since October 1942 the Division has done war work only.)

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and, therefore, constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

Changes in the Board of Regents during the fiscal year included the election at the Board meeting on January 16, 1942, of Chief

Justice Harlan F. Stone as Chancellor of the Institution, to succeed former Chief Justice Charles E. Hughes, and the appointment by Joint Resolution of Congress approved August 21, 1941, of the Honorable Frederic C. Walcott, a citizen of Connecticut, to succeed the late R. Walton Moore. By Joint Resolution of Congress approved August 21, 1941, Frederic A. Delano, of the city of Washington, D. C., was reappointed to succeed himself for the statutory term of 6 years.

The roll of regents at the close of the fiscal year was as follows: Harlan F. Stone, Chief Justice of the United States, Chancellor; Henry A. Wallace, Vice President of the United States; members from the Senate—Charles L. McNary, Alben W. Barkley, Bennett Champ Clark; members from the House of Representatives—Clarence Cannon, William P. Cole, Jr., Foster Stearns; citizen members—Frederic A. Delano, Washington, D. C.; Roland S. Morris, Pennsylvania; Harvey N. Davis, New Jersey; Arthur H. Compton, Illinois; Vannevar Bush, Washington, D. C.; and Frederic C. Walcott, Connecticut.

Proceedings.—The annual meeting of the Board of Regents was held on January 16, 1942. The regents present were Chief Justice Harlan F. Stone, Chancellor; Vice President Henry A. Wallace; Representatives Clarence Cannon, William P. Cole, Jr., and Foster Stearns; citizen regents Frederic A. Delano, Roland S. Morris, Harvey N. Davis, Vannevar Bush, and Frederic C. Walcott; and the Secretary, Dr. Charles G. Abbot.

The Board received and accepted the Secretary's annual report covering the year's activities of the parent Institution and the several Government branches. The Board also received and accepted the report by Mr. Delano, of the executive committee, covering financial statistics of the Institution; and the annual report of the Smithsonian Art Commission.

In his special report the Secretary outlined some of the more important activities carried on by the Institution and the branches during the year.

FINANCES

A statement on finances will be found in the report of the executive committee of the Board of Regents, page 99.

MATTERS OF GENERAL INTEREST

SMITHSONIAN RADIO PROGRAM

The educational radio program known as "The World Is Yours," sponsored jointly by the Smithsonian Institution, the United States Office of Education, and the National Broadcasting Co., was terminated with the broadcast of May 10, 1942, after nearly 6 years

of successful operation. On the air every week almost without a break for more than 300 weeks, the series finally was brought to an end because of the urgent demand of war agencies for radio time. In explaining the necessity for closing the program, Thomas D. Rishworth, director of public service programs, Eastern Division, National Broadcasting Co., wrote to the Institution:

> I regret that it was necessary to cancel "The World Is Yours" in view of its long and successful history as one of our oldest educational broadcasts * * * The war emergency has brought upon radio many difficulties that were unforseen, not the least of which is the impossibility of expanding a strictly limited schedule to meet the needs of all agencies involved in the war effort * * * I believe everyone will agree that through "The World Is Yours" you have made a unique contribution to the development of the educational significance of radio in terms that were interesting to all types of listeners.

"The World Is Yours," a half-hour dramatized program, first went on the air on June 7, 1936, and almost every week since that time it has presented over a Nation-wide National Broadcasting Company network some phase of science, invention, history, and art. The series from the beginning struck a responsive chord in radio listeners throughout the country. Supplementary articles on the subjects discussed were offered to listeners, and many thousands of those who responded took occasion to express enthusiastic commendation of the program. It was made very evident that the American public is keenly interested in science, history, and related fields if the subjects are brought alive by dramatization and if excessive technicality is avoided.

Radio proved to be an ideal aid in achieving a principal goal of the Institution, namely, the diffusion of knowledge. For this reason it was with great regret that "The World Is Yours" was brought to an end as one of the sacrifices that have to be made when the country is at war.

The subjects presented during the year up to the close of the series on May 10 were as follows: [1]

	1941
Thomas Jefferson	July 5
Builders of American Aircraft	July 12
Pirates of the Deep	July 19
Dust Storms	July 26
Herbert Ward	Aug. 2
Our Nearest Neighbor in Space	Aug. 9
John Ericsson	Aug. 16
Chemistry—and American Independence	Aug. 23
The Norsemen in Greenland	Aug. 30
Gilbert Stuart	Sept. 7
Cave and Cliff Dwellers	Sept. 14
Pompeii Lives Again	Sept. 21
Historical Gems	Sept. 28

[1] Because of National Broadcasting Co. commitments, no programs were given on November 16, 1941, and January 11, February 22, March 15, and April 12, 1942.

	1941	
Industry Calls on Physics	Oct.	5
Samuel Slater	Oct.	12
Insect Allies of Man	Oct.	19
South Sea Islanders	Oct.	26
The Story of Wheat	Nov.	2
Unsung American Heroes	Nov.	9
Arctic Explorers	Nov.	23
Hunting in Colonial Times	Nov.	30
Ancient Carthage	Dec.	7
Miracles of Modern Medicine	Dec.	14
A Great American Geologist	Dec.	21
Light that Heals	Dec.	28
	1942	
Our Expanding Knowledge	Jan.	4
Forests and the War	Jan.	18
Stephen Decatur—Naval Hero	Jan.	25
Zebulon Montgomery Pike	Feb.	1
Chemicals from the Air	Feb.	8
The Gasoline Engine	Feb.	15
The Musk Ox	Mar.	1
The Saga of the Comstock Lode	Mar.	8
The Fight on the Arikaree	Mar.	22
Bigelow and the Carpet Industry	Mar.	29
Balboa and the Discovery of the Pacific	Apr.	5
Australia	Apr.	19
China	Apr.	26
The Philippines	May	3
Russia	May	10

WALTER RATHBONE BACON SCHOLARSHIP

The Walter Rathbone Bacon scholarship of the Smithsonian Institution for 1941–1943 was awarded in July 1941 to Philip Hershkovitz, of the University of Michigan, for a study of the distribution of mammals in Colombia. On November 8, 1941, Mr. Hershkovitz departed from New York on the steamship *Platano* and arrived November 14 at Barranquilla, Colombia, where arrangements for field work were completed with the assistance of the Department of State through the Hon. Nelson R. Park, the American consul. After having obtained the necessary permits for travel and for the collecting of natural history specimens from the Governor of the Department of Atlántico, Mr. Hershkovitz was invited by Mr. Crump, owner of a ranch at Sabana Larga, to set up camp on his land. Collections were made in the northern portion of the Ciénaga de Guájaro near Arroya de Piedra and on Cerro de la Guayta from November 28 to December 18. Returning to Barranquilla, he examined the Indian burial ground uncovered at the Soledad airport south of that city, and with the help of P. J. De Guerin, office

engineer of Avionca, a subsidiary of the Pan-American Airways, excavated pottery and portions of human skeletons.

After some delay, Mr. Hershkovitz departed on January 3, 1942, from Barranquilla for Caracolicito, arriving there January 4. On invitation from the director, Sr. José I. Martinez, Mr. Hershkovitz made collections in the tropical forests surrounding Colonia Agrícola de Caracolicito from January 9 to March 16. From this region he moved camp to Pueblo Bello (Pueblo Viejo Sur) on the southern flank of the Sierra Nevada de Santa Marta, Department of Magdalena, and worked there from April 19 to June 6. As a result of centuries of deforesting, overgrazing, and burning by the Indians, the general appearance of this region is now that of a savanna with small stands of second-growth timber in the valleys and small patches of virgin forest on the inaccessible parts of the hills. Consequently, collecting did not produce as good results as had been anticipated. About the middle of June, collecting was begun at El Salado, about halfway between Pueblo Bello and Valencia.

ELEVENTH ARTHUR LECTURE

The late James Arthur, of New York, in 1931 bequeathed to the Smithsonian Institution a sum of money, part of the income from which should be used for an annual lecture on the sun.

The eleventh Arthur lecture, under the title "The Sun and the Earth's Magnetic Field," was given by John A. Fleming, director, department of terrestrial magnetism, Carnegie Institution of Washington, in the auditorium of the National Museum on February 26, 1942. The lecture is published in full in the General Appendix to this Report.

The 10 previous Arthur lectures have been as follows:

1. The Composition of the Sun, by Henry Norris Russell, professor of astronomy at Princeton University. January 27, 1932.
2. Gravitation in the Solar System, by Ernest William Brown, professor of mathematics at Yale University. January 25, 1933.
3. How the Sun Warms the Earth, by Charles G. Abbot, Secretary of the Smithsonian Institution. February 28, 1934.
4. The Sun's Place among the Stars, by Walter S. Adams, director of the Mount Wilson Observatory. December 18, 1934.
5. Sun Rays and Plant Life, by Earl S. Johnston, assistant director of the Division of Radiation and Organisms, Smithsonian Institution. February 25, 1936.
6. Discoveries from Eclipse Expeditions, by Samuel Alfred Mitchell, director of the Leander McCormick Observatory, University of Virginia. February 9, 1937.
7. The Sun and the Atmosphere, by Harlan True Stetson, research associate, Massachusetts Institute of Technology. February 24, 1938.
8. Sun Worship, by Herbert J. Spinden, curator of American Indian Art and Primitive Cultures, Brooklyn Museums. February 21, 1939.

9. Solar Prominences in Motion, by Robert R. McMath, director of the McMath-Hulbert Observatory of the University of Michigan. January 16, 1940.
10. Biological Effects of Solar Radiation on Higher Animals and Man, by Brian O'Brien, professor of Physiological Optics, University of Rochester February 25, 1941.

EXPLORATIONS AND FIELD WORK

Explorations, often in out-of-the-way corners of the earth, have always formed a major part of the Institution's program for the "increase and diffusion of knowledge." Although world conditions during the past year have made it either impracticable or undesirable to send out many of the expeditions that normally would have taken the field, nevertheless, even under the present unfavorable conditions it was found possible to carry on some field work in connection with researches previously commenced.

In astrophysics, the Institution's field observers carried on their study of the intensity of solar radiation at the three Smithsonian observing stations on Mount Montezuma, Chile, Table Mountain, Calif., and Burro Mountain, N. Mex. Observations were made on every suitable day throughout the year, and the results were transmitted to Washington where they are used in investigations on the variability of solar radiation and on the relation between this variability and the earth's weather.

In geology, Dr. W. F. Foshag directed an expedition in cooperation with the United States Geological Survey with the purpose of studying certain strategic-mineral resources of Mexico. Dr. Charles E. Resser continued his studies of Cambrian rocks from Montana into the Canadian Rockies, obtaining much new information and many desirable specimens pertaining to the ancient Cambrian period. Dr. G. Arthur Cooper made large collections of Carboniferous and Permian fossils in Texas and Oklahoma, including much material hitherto lacking in the National Museum collections. A third expedition to the Bridger Badlands of southwestern Wyoming in search of extinct vertebrate animals was directed by Dr. C. Lewis Gazin; many interesting exhibition and study specimens were brought back to the Museum, including a 1,270-pound slab containing 12 or 13 fossil turtles.

In biology, Dr. E. A. Chapin visited the island of Jamaica to continue his studies of the insect fauna with special reference to the termites. Large collections of the plants of Cuba were made by C. V. Morton, who spent 2 months on the island in botanical field work accompanied by two Cuban Government botanists.

In anthropology, Dr. T. D. Stewart visited Peru to make a scientific examination of the skeletal remains exposed in the numerous ancient cemeteries of that country; he also gathered information on the skeletal collections in Peruvian museums. As an extension of Smithsonian cave explorations in the Big Bend region of Texas, Walter W. Taylor investigated caves in the region of Ciénegas, Coahuila, Mexico, some 20 caves being excavated in the course of the work. Dr. Frank H. H. Roberts, Jr., conducted archeological investigations near the town of San Jon, eastern New Mexico, revealing four types of projectile points from four stratigraphic horizons, the oldest type in association with an extinct bison and with indications that it may be contemporaneous with the Folsom horizon. Dr. William N. Fenton recorded Iroquois songs in New York State and Canada in cooperation with the Division of Music in the Library of Congress.

PUBLICATIONS

The publications of the Institution and its branches, issued in several distinct series, constitute its chief means of accomplishing the "diffusion of knoweldge." The Smithsonian Annual Report contains, in addition to the Secretary's administrative report, a general appendix made up of selected nontechnical articles which together constitute a survey of the current state of knowledge in many fields of scientific investigation. The series Smithsonian Miscellaneous Collections provides an outlet for the results of researches by Smithsonian scientists or collaborators of the Institution without restriction as to the field covered. The Bulletin and Proceedings of the National Museum record the investigations of members of its staff, as well as of outside scientists, based on the great collections of the Museum. The Bulletins of the Bureau of American Ethnology deal with various phases of the study of the American Indians. Other series include the Annals of the Astrophysical Observatory, the title of which is self-explanatory, and Smithsonian War Background Studies, a new series intended to disseminate information on the peoples and areas involved in the present war.

During the year, 100 publications were issued, 51 by the Institution proper, 44 by the National Museum, 4 by the Bureau of American Ethnology, and 1 by the Astrophysical Observatory. The titles, authors, and other details of these publications will be found in the report of the chief of the editorial division, appendix 11. The total number of publications distributed was 162,525.

Outstanding among the year's publications may be mentioned volume 6 of the Annals of the Astrophysical Observatory, covering 20 years' investigations of the solar radiation; a paper by the late Carl Whiting Bishop entitled "Origin of the Far Eastern Civiliza-

tions: a Brief Handbook"; a paper by Frank C. Hibben on "Evidences of Early Occupation in Sandia Cave, New Mexico * * *," which throws more light on the earliest occupants of this continent; a new edition of the "Handbook of the National Aircraft Collection," by Paul E. Garber; and another volume in the series on life histories of North American birds by Arthur Cleveland Bent, "Life Histories of North American Flycatchers, Larks, Swallows, and Their Allies." The continued demand for the Smithsonian volumes of tables, in large part from war agencies, necessitated a reprinting of the Smithsonian Meteorological Tables and the Smithsonian Physical Tables.

LIBRARY

In common with the scientific libraries of international scope, the Smithsonian library suffered severe disruption from the impact of the war. Publication of scientific books and periodicals declined abroad, and those that were issued were obtainable only with great difficulty if they could be obtained at all. After Pearl Harbor, of course, library exchanges ceased with nearly all countries except those in the Western Hemisphere. The brighter side of the picture, however, is the service the library has been able to render to war agency officials, not only by providing access to published information, but also by putting inquirers in touch with members of the Institution's staff having specialized knowledge and by arranging introductions to outside sources. Taking advantage of the decreased amount of time devoted to foreign exchanges, the library staff grasped the opportunity of recataloging older material that has long needed attention and of strengthening and extending domestic exchanges. As usual many gifts came to the library from associations and individuals, noteworthy among them being 724 publications from the American Association for the Advancement of Science, 68 from the American Association of Museums, and a library of some 2,000 items on Copepoda assembled by the late Dr. Charles Branch Wilson and presented by his son, Carroll A. Wilson. The most important of the changes in the library personnel was the retirement on January 31, 1942, of William L. Corbin, librarian for more than 17 years, and the appointment to succeed him of Mrs. Leila F. Clark, who had been assistant librarian in charge of the National Museum library since 1929. The year's statistics show 5,685 accessions, bringing the library's total holdings to 867,200; 229 new exchanges arranged; 4,040 "wants" received; 4,775 volumes and pamphlets cataloged; 29,826 cards filed in catalogs and shelflists; 12,258 periodicals entered; 9,978 books and periodicals loaned; and 1,400 volumes sent to the bindery.

Respectfully submitted.

C. G. Abbot, *Secretary.*

APPENDIX 1

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operation of the United States National Museum for the fiscal year ended June 30, 1942:

Appropriations for the maintenance and operation of the National Museum for the year totaled $830,978, which was $12,673 more than for the previous year.

COLLECTIONS

Additions to the collections of the Museum aggregated 1,388 separate accessions, comprising 284,582 individual specimens, a decrease, compared with the previous year, of 130 accessions and 42,104 specimens. Distribution of these additions among the five departments was as follows: Anthropology, 3,000; biology, 245,200; geology, 32,418; engineering and industries, 2,415; and history, 1,549. These acquisitions were received principally as gifts from individuals, or as a result of expeditions sponsored by the Smithsonian Institution. All are listed in detail in the full report on the Museum, published as a separate document, but the more important are summarized below. The total number of catalog entries in all departments is now 17,578,240.

Anthropology.—The division of archeology received 68 Greek, Roman, and Egyptian specimens collected by Thomas Nelson Page; several examples of ancient Persian pottery and armor; about 700 artifacts excavated in Florida; more than 200 stone, bone, pottery, and shell specimens from the old Indian village site of Potawomeke, Stafford County, Va.; and 175 artifacts from southern California. In ethnology, blankets, jewelry, and wearing apparel, representing the culture of the Navaho of Arizona, the Zuñi, the Tule Indians of the San Blas coast of Panama, the Indians of Guatemala, the Chocó Indians of Darién, and the Comanche Indians were of outstanding interest. The ethnological collections were also augmented by masks, food bowls, head rests, and cult objects from voodoo shrines in Haiti, and cutting and slashing weapons made by the Moro of Mindanao, P. I. Among the important accessions to the collection of ceramics were a glazed Parian pitcher made about 1850 in Vermont; a Bilston snuffbox made in 1759; an interesting collection of

eighteenth- and nineteenth-century European ware including pottery, porcelain, and glass; and examples of Sandwich glass dating to about 1840.

Biology.—The important mammalian accessions of the year included 30 Antarctic seals, representing 4 genera and including 3 skins and 3 skeletons of the rare Ross's seal; 151 mammals from Mohave County, Ariz.; 54 Manchurian mammals, one of which was new to science; a Tibetan fox skin (*Cynalopex corsac*), a genus hitherto unrepresented in the Museum, from Yunnan, China; and 35 bats collected in caves near Washington.

Among the most important and valuable avian accessions of the year are 1,845 skins collected in Colombia by Dr. Alexander Wetmore and M. A. Carriker, Jr.; 447 birds from Brazil from the Rockefeller Foundation; bird skins from Mexico, Manchuria, Paraguay, and Alaska. Skins representing forms new to the Museum collection included 5 from Venezuela, 1 from Chile, and 1 from Ecuador. The Fish and Wildlife Service of the Department of the Interior transferred 53 birds from various parts of the world and 3 sets of eggs of rare North American waterfowl. Of the skeletal material acquired, 63 skeletons were collected by members of the staff, and 90 were received from the National Zoological Park.

An outstanding accession of the division of fishes consisted of 14,219 specimens from the area between Peru and Alaska, received by transfer from the United States Fish and Wildlife Service. President Franklin D. Roosevelt presented a fine "mother of eels," *Macrozoarces americanus*, caught off Nova Scotia on August 9, 1941. The type material of *Hypsoblenniops rickettsi* was included in a collection of 107 specimens of fishes from the Gulf of California. New material, received in exchange, included the following: Holotypes and paratypes of new species from Liberia and Cameroons; 29 paratypes from Brazil, Yucatán, and Venezuela; a cotype of *Elanura forficata* from Bering Sea; and one paratype each of *Sebastodes owstoni*, *Nectarges nepenthe*, *Machaerenchelys vanderbilti*, and *Spinoblennius spiniger*.

The division of insects received the collection of Hemiptera built up by Waldo L. McAtee, of the Fish and Wildlife Service, consisting of approximately 25,000 specimens and containing much type material. Mr. McAtee also presented volumes and papers on entomological subjects needed for the division's sectional library. The collection of the late George P. Engelhardt and his entomological books were also acquired by the division—these in addition to the more than 5,000 specimens of Lepidoptera presented by Mr. Engelhardt before his death. The material collected by the curator, Dr. Edward A. Chapin, during an expedition in Jamaica, consisting of about 7,600 specimens, mostly termites, was accessioned during the year. A large

collection, mostly beetles, was received as a gift from the Colombian Government. Among other large lots of insects received was a collection of 52,000 specimens taken by the United States Bureau of Entomology and Plant Quarantine, in connection with its activities.

Accessions to the division of marine invertebrates included 17 species new to the collections, representing crayfish, crabs, stomatopods, pycnogonids, ostracods, turbellarian and sipunculid worms, earthworms, rotifers, sponges, and barnacles. The division's sectional library received as a bequest from Dr. Charles Branch Wilson a comprehensive library (approximately 2,500 books and pamphlets) on copepods. Among the more important accessions received by the division of mollusks during the year was a collection made by Dr. Alexander Wetmore and M. A. Carriker, Jr., in Colombia. This collection included several new species of mollusks. Two purchases were made through the Frances Lea Chamberlain fund, consisting of 203 lots of 843 specimens. Several large collections of mollusks were received, representing the fauna of Fiji, Australia, New Zealand, Costa Rica, and Hawaii, as well as various localities in the United States. Many smaller accessions included types of new species. Additions to the helminthological collection also contained numerous types and cotypes. The Museum's collection of corals was augmented by 447 specimens, and among the more important accessions of the division of echinoderms is the first specimen of the brittlestar *Ophiocoma aethiops* known from Peru.

Among the more important accessions recorded by the division of plants (National Herbarium) was a lot of 2,169 specimens received in continuation of exchange from the Instituto de Ciencias Naturales, Bogotá, Colombia. A cooperative project between this institution and the National Museum now in preparation, a descriptive Flora of Colombia, will include a report on the above-mentioned material.

Geology.—Among the 156 minerals added by purchase to the Roebling collection was a large, deeply etched aquamarine from Agua Preta, Minas Geraes, Brazil, the finest single specimen acquired during the year. Other accessions included exceptional examples of copper minerals and lead carbonate, an unusual crystallized turquoise, a monazite crystal from Brazil, and a mass of the phosphate lithiophilite. Three acquisitions of exceptionally fine minerals were obtained by purchase from the collection of Dr. Otto Runge through the Canfield fund. The most outstanding additions to the gem collection came through a bequest of Mrs. Mary Vaux Walcott, among which a valuable 12-carat alexandrite, a string of pearls, and 14 necklaces of gem quality are worthy of special mention. The geological collections were also augmented by several important specimens of meteorites and ores, among them a complete specimen of the

Rose City, Mich., stony meteorite, weighing 2,690 grams, one of the largest individuals of that fall, presented by Dr. Stuart H. Perry, and a 184-pound mass of cassiterite from Goodwin Gulch, Stewart Peninsula, Alaska, perhaps the largest single piece of this tin mineral ever found.

Outstanding among the accessions by the division of invertebrate paleontology and paleobotany are a lot of more than 1,500 type specimens of fossil invertebrates; 4 tons of limestone blocks containing beautifully preserved silicified fossils obtained by Dr. G. A. Cooper in the Permian formations of the Glass Mountains of Texas; and 8,000 invertebrate fossils obtained by Dr. C. E. Resser from the Cambrian and Devonian rocks of Montana, Utah, and the Canadian Rockies.

Engineering and Industries.—Scale models of historic aircraft formed the largest group of important objects received by the division of engineering. Among these are models of 10 winners of the Thompson Trophy air races and a model of Sikorsky's 4-motor biplane, *Grand*, of 1913, which is called the first successful 4-motor airplane. A timely addition to the division's extensive series of aircraft engines is an example of the Allison liquid-cooled internal combustion engine, type V–1710–C, which represents one of industry's great contributions to the present war. Another very timely accession is a ¼-ton, 4-wheel-drive reconnaissance and command automobile, or "jeep," lent by the War Department. A transparent, plastic-body 1939 Pontiac automobile, received as a loan, fills the division's need for a late-model car.

With the consent of interested persons, the material contained in boxes deposited in the care of the Smithsonian Institution by Alexander Graham Bell in 1880 and 1881 was transferred to the division of engineering. Included are several photophone transmitters, selenium cell elements of receivers, an electrotype phonogram, and a graphophone equipped with a reproducing element designed to reproduce sound through the medium of a jet of air without mechanical contact with the record.

The most valuable object added to the medical exhibit was the first Emerson iron lung, completed in 1931, and used for several years to produce artificial respiration.

The most noteworthy accession in graphic arts was the gift of 183 Currier and Ives prints previously loaned to the division of graphic arts by Miss Adele S. Colgate. This accession was reported and described briefly in the report for 1941. With the cooperation of the Evening Star Newspaper Co. of Washington, the division's exhibit showing the steps in the printing of a newspaper was entirely renovated by the substitution of 23 new specimens to replace those now obsolete.

History.—The art material accessioned by the division of history includes a water-color sketch, painted in 1918, by Georges Scott, emblematic of the cordial relations existing between France and the United States. For the numismatic collection the Treasury Department forwarded a number of California gold tokens, coins, and examples of the bronze, nickel, and silver coins struck at the Denver, Philadelphia, and San Francisco mints in 1941. The philatelic material was increased by 1,301 specimens, which were transferred from the Post Office Department. Among these are stamps for countries now occupied by Germany, including German stamps overprinted "Luxemburg," and stamps issued by Germany for Poland.

EXPLORATIONS AND FIELD WORK

Explorations by members of the Museum staff have produced valuable information and highly useful series of specimens in various fields. The work has been made possible mainly by funds provided by the Smithsonian Institution, and by interested friends. With the entry of the United States into the war in December, the program of field activities was definitely curtailed. The expeditions from that date were those already in the field, or those that were required because of commitments previously made. Though the scope of the work has been decidedly less than in normal years, valuable results have been obtained.

Anthropology.—Walter W. Taylor, Jr., honorary collaborator in anthropology, completed archeological explorations around Cuatro Ciénegas in Coahuila, northern Mexico, which he inaugurated during the previous fiscal year. He conducted excavations in Fat Burro Cave and in Nopal Shelter, in Canyon de Jora, about 21 miles west of Cuatro Ciénegas. He then moved camp to Sierra de San Vicente, 20 miles southeast of Ciénegas, where he excavated a large site called Frightful Cave, located in the only through canyon in the San Vicente range. In this cave, which measures about 200 feet long and tapers in width from 30 feet at the entrance to 3 feet at the rear, the deposits ranged in depth from 10 feet to 3 feet, and consisted of compact floors, over which were superimposed strata of fire-cracked stones, ash, and fiber. Noteworthy specimens recovered from Fat Burro Cave consist of an atlatl, or throwing-stick foreshaft, with an arrow attached by sinew; a series of split-twig loops, comparable to those from the Big Bend area in Texas; stone projectile points similar to those from caves along the Pecos River, Texas; and a few pieces of split-stitch basketry. From Frightful Cave he recovered twilled woven bags filled with buckeyes, grooved clubs, four distinct types of fiber sandals, twined woven mats, and aprons. All the material collected was packed and transported to Mexico City for inspection by the scientists of the Instituto Nacional de Anthro-

pología e Historia, where Mr. Taylor received every courtesy from the Director of the Institution, Sr. Lic. Alfonso Caso, and the Director of the Department of Prehispanic Monuments, Sr. Ing. Ignacio Marquina.

From the end of May to the middle of June 1942, Frank M. Setzler, head curator of the department of anthropology, was detailed to the National Park Service for the purpose of directing a rapid archeological reconnaissance within the canyons formed by the Yampa and Green Rivers in northwestern Colorado and eastern Utah, to locate and evaluate the prehistoric caves, shelters, and village sites within an area that may be inundated eventually, if proposed dams are built along these rivers. The expedition traveled by boat through the various rapids within the canyon, and discovered and tested numerous sites. A detailed report covering the results of these investigations was prepared and submitted to the National Park Service before the close of the fiscal year.

Biology.—In March, M. A. Carriker, Jr., carrying on the work begun last year with Dr. Wetmore, continued the study and collection of birds in northeastern Colombia. From Codazzi, in the Department of Magdalena, he traveled into the mountains to establish a base that gave access to the higher peaks along the Venezuelan border. These investigations were supplemented by collections from the lowland areas, which were of value in connection with materials obtained in March 1941 at Caracolicito, in the drainage of the Río Ariguaní. At the close of the fiscal year these studies, which were made possible by the W. L. Abbott fund of the Smithsonian Institution, were still in progress.

Dr. Leonard P. Schultz, curator of fishes, was absent from February 1 to May 28 in Venezuela in connection with the program of the Department of State for promoting cultural relations with other American countries. Dr. Schultz spent 2 weeks in Caracas, where he consulted with various scientific groups, and the remainder of his time in the Maracaibo Basin, studying the fish fauna of that region. His work there was made possible by the friendly cooperation of the Lago Petroleum Corporation at Maracaibo and Lagunillas. For 8 days Dr. Schultz collected in the valleys of the Río Motatán, Río Chama, Río Catatumbo, and Río Torbes, all in the Andes. He obtained about 10,000 fish specimens, including approximately 115 species, and other natural-history material. The fish collection is the most complete one that has been made in this region and will afford valuable new information in this field.

Dr. E. A. Chapin, curator of insects, worked for 6 weeks in Colombia, in connection with the above-mentioned program of the Department of State. For 5 weeks he was in the vicinity of Bogotá, mainly at the Instituto de Ciencias Naturales in the University

Center. Through the courtesy of Dr. Armando Dugand, Director of the Instituto, Dr. Chapin's researches were conducted with the close cooperation of Luis M. Murillo, chief entomologist of the Colombian Government, Francisco Otoya, assistant entomologist, and Hernando Osorno, preparator. Mr. Murillo conducted several field trips that permitted Dr. Chapin to become acquainted with some of the major entomological problems of the country. These included investigations in the citrus regions near Cachetá, Pacho, and Guateque, and two trips into the Páramo near Guasca. Study in the Bogotá area was accompanied by a tour of other scientific agencies in Colombia. Dr. Chapin visited the agricultural institute at Medellín, where work on the collection of insects is under the direction of Dr. F. L. Gallego. The party, consisting of Messrs. Murillo, Otoya, and Cabal (an entomological student), and Dr. and Mrs. Chapin, then proceeded to the Agricultural Experiment Station at Palmira. While they were in Cali Dr. Belisario Losada escorted the party on a collecting trip into the Cordillera. They then returned to Bogotá for a final week of work at the Instituto, where special attention was given to the family Coccinellidae, which is of considerable economic importance in Colombia. Plans were formulated for further collaboration between the Instituto and the United States National Museum, with a monographic account of the Coccinellidae of Colombia as the end in view.

C. V. Morton, assistant curator of plants, spent October and November in Cuba, under the sponsorship of the National Museum and the Department of State, for the dual purpose of botanical field work and the furthering of cooperation with Cuban scientists. Mr. Morton was occupied part of the time in making partial catalogs of the ferns in various herbaria. In cooperation with the Cuban Department of Agriculture, and in association with Messrs. Acuña and Alonzo, of the Estacíon Agronómica at Santiago de Las Vegas, he also undertook field work in the mountainous part of Oriente, especially on the Sierra Nipe, and the northern slopes of the Sierra Maestra. Later he made collections in the Trinidad Mountains of Las Villas, with the Harvard Botanical Garden at Soledad as a base, and, through the friendly interest of the Colegio de La Salle of Habana, in the Sierra de Los Organos in Pinar del Rio. These expeditions resulted in the collection of 6,000 specimens, representing approximately 1,600 numbers.

Dr. E. H. Walker, assistant curator of plants, was occupied for a week in June in the Piedmont and the Blue Ridge Mountains of North Carolina and South Carolina, making botanical collections. Under Dr. Walker's leadership, local field work has been carried on by members of the Conference on the District of Columbia Flora.

Geology.—Field trips to the West for vertebrate and invertebrate paleontological collections were specially successful this year.

Dr. C. E. Resser, curator of invertebrate paleontology spent part of the summer in Montana, and part in the Canadian Rockies. Accompanied by George Burke Maxey, of Missoula, Mont., he first made a brief collecting trip to the northern Wasatch Mountains in search of Cambrian fossils. In the Canadian Rockies they devoted the first 2 weeks to the study of Cambrian beds in the mountains adjacent to the Bow Valley, chiefly at Castle Mountain, and in the Valley of the Ten Peaks at Moraine Lake, where they found excellent fossils high on nearby Eiffel Peak. They worked for more than a month from a base camp at the foot of Mount Stephen, 3 miles west of Field, covering an area as far east as Lake Louise and west beyond Emerald Lake. For nearly three-quarters of a century the fossil bed on Mount Stephen has been known to paleontologists throughout the world. The trail leading up from Field is only 3 miles long, but it climbs 2,700 feet. Entire trilobites are common, and many other fossils are obtainable. With the permission of the Canadian National Park Service, Dr. Resser and his party collected excellent material. Later it was Dr. Resser's privilege to follow the trail on the north side of the Kicking Horse River to Burgess Pass, made famous by Dr. C. D. Walcott, former Secretary of the Smithsonian Institution, by his discovery of the most remarkable fauna of these earliest geological periods yet found.

Dr. G. Arthur Cooper, associate curator of vertebrate paleontology, collected fossils in Texas and Oklahoma. In Fort Worth he met Dr. N. D. Newell, and for 3 days, together with Dr. Ralph H. King, of the Kansas Geological Survey, they collected in north-central Texas, proceeding from there to Marathon, Tex., where they spent a month collecting Permian limestone blocks containing silicified fossils. In late July Dr. Cooper met Mrs. J. H. Renfro and her daughter at Fort Worth for investigations of the Pennsylvanian rocks of Jack County and the Cretaceous rocks around Fort Worth, where they obtained many interesting fossils. In August Dr. Cooper collected Devonian and Ordovician fossils at Ardmore, Okla., and then continued to Ada, Okla., where he was joined by Dr. C. Lalicker, of the University of Oklahoma, who guided him to numerous localities where free Pennsylvanian fossils are obtainable. At Muskogee he made a fine collection of Mississippian fossils, and from there made a short trip into southern Kansas to collect Pennsylvanian fossils. This is the third season that Dr. Cooper has collected in these fields, and with the 4 tons of blocks containing silicified fossils collected in the Glass Mountains, and many thousand specimens of free Pennsylvanian fossils obtained this year in north-central Texas and Oklahoma, the

Museum now has an important series of Permian and Pennsylvanian fossils.

As the field expedition in vertebrate paleontology into the Upper Cretaceous and Paleocene regions of Utah, under Dr. C. L. Gazin, associate curator, extended well into the present year, only brief mention was made of it in last year's report. The party succeeded in obtaining some unusually good material of the smaller mammals, the most outstanding being the lower jaws and fragmentary parts of the skeleton of the rare *Stylinodon*, and good specimens of the larger forms such as *Hyrachyus* and *Paleosyops*. Other interesting materials are a large slab of turtle remains, which will make an interesting exhibition piece, and a small collection of Paleocene mammals from the Alma formation in western Wyoming.

Starting early in June 1942, C. W. Gilmore, curator of vertebrate paleontology, led a party to explore the Oligocene rocks of eastern Wyoming and western Nebraska, where good progress in the discovery of mammalian remains has already been reported. Mr. Gilmore had as assistant the experienced collector George H. Sternberg, and was accompanied also by Alfonso Segura Paguaga, of the Museo Nacional, San José, Costa Rica. The account of operations will be carried in next year's report.

In continuation of former field work in Mexico, Dr. W. F. Foshag, curator of mineralogy and petrology, returned to that country in February, under a cooperative arrangement with the United States Geological Survey and with the Board of Economic Warfare, to direct further strategic-mineral work. At the end of the fiscal year he was still in the field.

From March 17 until May 15, 1942, Dr. Remington Kellogg, curator of mammals, with Watson M. Perrygo, scientific aid, as assistant, was engaged in excavating Rampart Cave, in the lower cliff-forming member of the Middle Cambrian Peasley limestone, on the south side of the lower end of the Colorado River canyon, in the Boulder Dam National Recreational Area, Ariz. This was a cooperative project, undertaken by the Smithsonian Institution and the National Park Service. The latter agency detailed Edward T. Schenk, senior geological foreman, Samuel D. Hendricks, assistant engineer, Dr. Gordon C. Baldwin, archeologist, Ray Poyser, boat pilot, and seven men from the Boulder City Civilian Conservation Corps camp for intervals of varying length to assist in the work. The party obtained skeletal remains of ground sloths, mountain goats, pumas, marmots, skunks, and several species of birds, lizards, and snakes. Part of the cave was left undisturbed as a display for visitors, if it should seem desirable to develop it for that purpose at some time in the future.

MISCELLANEOUS

Visitors.—Curtailment of travel because of the war had less effect than anticipated upon the number of visitors at the various Museum buildings. The total recorded during the year was 2,042,817, as against 2,505,817 for the previous year. The largest attendance for a single month was in August 1941, with 381,952 visitors, and the second largest was in July 1941, with 329,927. The attendance in the four Smithsonian and Museum buildings was as follows: Smithsonian Building, 375,630; Arts and Industries Building, 936,625; Natural History Building, 622,989; Aircraft Building (closed from July to November 6), 107,573.

Publications and printing.—The sum of $34,750 was available during the fiscal year 1942 for the publication of the Annual Report, Bulletins, and Proceedings. Forty-four publications were issued—the Annual Report, 3 Bulletins, 1 part each of Bulletins 50, 82, and 161, 1 separate paper from volume 28 of the Contributions from the United States National Herbarium, and 36 separate Proceedings papers. Titles and authors of these publications will be found in the report on publications, appendix 11.

Volumes and separates distributed during the year to libraries, institutions, and individuals throughout the world aggregated 82,545 copies.

Special exhibits.—Fifteen special exhibits were held during the year under the auspices of various educational, scientific, recreational, and governmental groups. In addition the department of engineering and industries arranged 21 special displays—10 in graphic arts and 11 in photography.

CHANGES IN ORGANIZATION AND STAFF

In the department of anthropology, Dr. T. Dale Stewart succeeded to the curatorship of physical anthropology on April 1, 1942, following the retirement of Dr. Aleš Hrdlička, and Dr. Marshall T. Newman was appointed associate curator on June 22, 1942.

In the department of biology, division of birds, Herbert G. Deignan was advanced to associate curator on February 1, 1942, and S. Dillon Ripley, 2d, was appointed assistant curator on March 13, 1942. In the division of mammals, Dr. David H. Johnson was appointed associate curator on August 18, 1941. On February 1, 1942, Dr. Egbert H. Walker was reallocated to assistant curator, division of plants.

In the department of geology, the division of physical and chemical geology (systematic and applied) and the division of mineralogy and petrology were combined under the title of division of mineralogy and petrology, with Dr. William F. Foshag as curator and Ed-

ward P. Henderson as associate curator. The division of stratigraphic paleontology became the division of invertebrate paleontology and paleobotany, with Dr. Charles E. Resser as curator and Dr. G. Arthur Cooper as associate curator. These changes were effective June 17, 1942.

On March 1, 1942, the following members of the staff were advanced to associate curator: In the department of anthropology, J. E. Weckler, Jr., and Waldo R. Wedel; in the department of biology, Doris M. Cochran, R. E. Blackwelder, C. R. Shoemaker, and Harald A. Rehder; in the department of geology, C. Lewis Gazin; in the department of engineering and industries, Paul E. Garber, William N. Watkins, and A. J. Olmsted. On the same date, B. O. Reberholt, of the division of mineralogy and petrology, was made senior scientific aid.

On February 1, 1942, Mrs. Leila F. Clark was appointed librarian of the Smithsonian Institution, in the position made vacant through the retirement of William L. Corbin, and Elisabeth P. Hobbs was advanced to associate librarian on May 21, 1942.

Honorary appointments were conferred on W. W. Taylor, Jr., as collaborator in the department of anthropology, July 1, 1941; on Dr. Aleš Hrdlička, as associate in anthropology, April 1, 1942; and on Dr. Henry Pittier, as associate in botany, September 25, 1941.

The following employees were furloughed indefinitely for military service: Clyde E. Bauman, January 22, 1942; Stephen C. Stuntz, March 9, 1942; Shallie Youngblood, May 20, 1942; and Earl W. Cook, May 24, 1942.

Employees who left the service through the operation of the retirement act were as follows: For age, Dr. Aleš Hrdlička, curator, on March 31, 1942, with 38 years 11 months of service; Joseph P. Germuiller, guard, on December 8, 1941, with 23 years 3 months of service. Through optional retirement: Fred Kaske, scientific aid, with 39 years 11 months of service, on May 31, 1942, and Samuel P. Darby, guard, with 33 years 7 months of service, on May 31, 1942. Through disability retirement: William H. Smith, lieutenant of the guard, on December 31, 1942; Robert G. Tegeler, guard, on October 1, 1941; Thomas J. Shannon, guard, on November 14, 1941; and Arthur O. Wickert, under mechanic (electrician's helper), on January 31, 1942.

The honorary appointments of W. L. McAtee, acting custodian, section of Hemiptera, and of W. W. Taylor, Jr., collaborator in anthropology, terminated on June 30, 1942.

The Museum lost through death 3 active workers: Joseph R. Riley, associate curator, division of birds, on December 17, 1941; William H. Bray, preparator, department of anthropology, on December 18,

1941; Jacob C. Earnhart, guard, on February 10, 1942; and 5 honorary members of the staff who were long associated with its activities: Dr. Charles Branch Wilson, honorary collaborator in copepods, division of marine invertebrates, on August 18, 1941; Dr. Hugh M. Smith, associate in zoology, on September 28, 1941; Dr. Casey Albert Wood, collaborator, division of birds, on January 26, 1942; Dr. C. Hart Merriam, associate in zoology, on March 19, 1942; and Dr. William Schaus, honorary assistant curator of insects, on June 20, 1942.

Respectfully submitted.

ALEXANDER WETMORE, *Assistant Secretary.*

DR. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit, on behalf of the Board of Trustees of the National Gallery of Art, the fifth annual report of the Board covering its operations for the fiscal year ended June 30, 1942. This report is being made pursuant to the provisions of the act of March 24, 1937 (50 Stat. 51), as amended by the public resolution of April 13, 1939 (Pub. Res. No. 9, 76th Cong.).

ORGANIZATION AND STAFF

During the fiscal year ended June 30, 1942, the Board was comprised of the Chief Justice of the United States, Harlan F. Stone, who succeeded the Honorable Charles Evans Hughes as Chief Justice and took office on July 3, 1941; the Secretary of State, Cordell Hull; the Secretary of the Treasury, Henry Morgenthau, Jr.; and the Secretary of the Smithsonian Institution, Dr. C. G. Abbot, ex officio; and five general trustees, David K. E. Bruce, Duncan Phillips, Ferdinand Lammot Belin, Joseph E. Widener, and Samuel H. Kress.

At its annual meeting held February 9, 1942, the Board reelected David K. E. Bruce, President, and Ferdinand Lammot Belin, Vice President of the Board, to serve the ensuing year. The executive officers continuing in office during the year were Donald D. Shepard, Secretary-Treasurer and General Counsel; David E. Finley, Director; Harry A. McBride, Administrator; John Walker, Chief Curator; and Macgill James, Assistant Director. At the annual meeting the Board elected Chester Dale of New York as an honorary officer of the Gallery, giving him the title of Associate Vice President. At a meeting of the Board held December 29, 1941, the Board provided for the appointment of Otto R. Eggers and Daniel P. Higgins, constituting the firm of Eggers & Higgins of New York, as consultant architects for the National Gallery of Art. During the year, George T. Heckert was appointed Assistant Administrator, such appointment being made possible because of the reclassification of his office by the Civil Service Commission.

Also at the annual meeting the Board, pursuant to its bylaws, constituted its three standing committees as follows:

EXECUTIVE COMMITTEE

Chief Justice of the United States, Harlan F. Stone, chairman.
David K. E. Bruce, vice chairman.
Secretary of the Smithsonian Institution, Dr. C. G. Abbot.
Ferdinand Lammot Belin.
Duncan Phillips.

FINANCE COMMITTEE

Secretary of the Treasury, Henry Morgenthau, Jr., chairman.
David K. E. Bruce, vice chairman.
Secretary of State, Cordell Hull.
Ferdinand Lammot Belin.
Samuel H. Kress.

ACQUISITIONS COMMITTEE

David K. E. Bruce, chairman.
Ferdinand Lammot Belin, vice chairman.
Duncan Phillips.
Joseph E. Widener.
David E. Finley, ex officio.

All positions with the Gallery, with the exception of the executive and honorary officers, are filled from the registers of the United States Civil Service Commission or with its approval. By June 30, 1942, the permanent Civil Service staff numbered 234 employees. Since the opening of hostilities, 12 members of the staff had joined the armed forces.

APPROPRIATIONS

For salaries and expenses, for the upkeep and operation of the National Gallery of Art, the protection and care of the works of art acquired by the Board, and all administrative expenses incident thereto, as authorized by the act of March 24, 1937 (50 Stat. 51), as amended by the public resolution of April 13, 1939 (Pub. Res. No. 9, 76th Cong.), the Congress appropriated for the fiscal year ending June 30, 1942, the sum of $533,300, to cover the first full year of operation. From this appropriation the following expenditures and encumbrances were made:

EXPENDITURES AND ENCUMBRANCES

Personal services	$353, 583. 22
Printing and binding	6, 880. 70
Supplies and equipment, etc	133, 087. 18
Reserve	36, 080. 00
Unencumbered balance	3, 668. 90
Total	533, 300. 00

ATTENDANCE

The total attendance for the first year during which the National Gallery was open was 2,005,328, a daily average of over 5,500 visitors.

A unique record for museum attendance was established on July 7, 1941, when the one millionth visitor entered the Gallery, less than 4 months after its dedication. The Gallery is open to the public each week day of the year between the hours of 10 a. m. and 5 p. m., except for Christmas and New Year's Day, and on Sundays from 2 until 5 p. m.

On June 7, 1942, the Gallery inaugurated an experimental series of Sunday evening openings, primarily for the benefit of men in the armed forces and war workers in the city. The exhibition galleries were open from 2 to 10 p. m., and orchestral concerts during the summer months were given, through the generosity of Chester Dale, from 7:15 to closing time. Special lectures with color slides were given by the Gallery staff at 7:30 and 8:30 in the lecture hall, and the cafeteria in the Gallery building was open from 4 to 8. Each Sunday evening from 50 to 75 service men were invited by members of the staff and by friends of the Gallery to supper in the cafeteria. On Sundays the attendance frequently exceeded 8,000; and, in view of the popularity of the Sunday evening openings, it was decided to continue the arrangement indefinitely.

Through the generosity of Mrs. Matthew John Whittall, the Gallery presented in the lecture hall on the ground floor, a concert by the Budapest String Quartet on Sunday afternoon, May 31, 1942. This concert had been planned for men in the Service and their friends, the program lasting approximately 1 hour.

PUBLICATIONS

In the information rooms in the Gallery building, a general information booklet is given without charge to visitors on request. It contains a short survey of the collections and information which has been found to be of great assistance to visitors to the Gallery. Also available, are catalogs of the paintings and sculpture, a complete book of illustrations of all the works of art in the Gallery's collection, color reproductions, and postcards in color and black and white, all made available through the Publications Fund. These publications are on sale at moderate cost.

AIR-RAID PROTECTION

Immediately following the outbreak of hostilities on December 7, 1941, the National Gallery building was blacked out nightly. The staff was organized into five air-raid services: Fire, police (including morale), health (first aid), maintenance, and evacuation. Drills were started and repeated frequently in order that the units might operate smoothly in the event of an actual air raid. Drills that were held in coordination with the District of Columbia authorities, when visitors were in the building, evidenced the measure of efficiency

which had been reached by the protective organization in the Gallery. Purchases of air-raid protection equipment were also made as promptly as possible and to the extent permitted by the great demand for such equipment.

REMOVAL OF WORKS OF ART TO A PLACE OF SAFEKEEPING

At a special meeting held December 29, 1941, the Board approved the recommendations of the executive officers of the Gallery that a limited number of the most fragile and irreplaceable works of art in the national collection be removed to a place of greater safety, in view of the responsibility which rests with the Trustees for safeguarding the collection. Early in January, therefore, the paintings and sculpture to be evacuated were removed from exhibition and shipped under guard to the place of safety which had been determined upon and adapted for the purpose. All of the works of art arrived in excellent condition. While thus in storage, they are under constant guard by members of the National Gallery guard force and under supervision and inspection by a member of the curatorial staff of the Gallery.

Beyond this partial evacuation, however, it was the expressed belief of the Trustees that the Gallery has a duty to the public (as a unit of the Government establishment), and an obligation as a source of recreation and education to continue its activities, and even increase them, as far as practicable, in wartime.

ACQUISITIONS

GIFTS OF PRINTS

On February 9, 1942, the Board of Trustees accepted from Philip Hofer a woodcut, "Saint Sebastian," by Hans Baldung (Grien), to be added to his earlier gift of prints which was included in last year's Annual Report; and again on April 27, 1942, the Board accepted a gift of 58 prints from Miss Elisabeth Achelis.

GIFTS OF PAINTINGS AND SCULPTURE

On September 8, 1941, the Board of Trustees accepted from Mr. and Mrs. Peter H. B. Frelinghuysen the gift of two paintings by Goya:

Portrait of Dona Bartolome Sureda
Portrait of Dona Teresa Sureda

both given in memory of Mrs. Frelinghuysen's mother and father, Mr. and Mrs. H. O. Havemeyer. These paintings are now on exhibition.

On February 9, 1942, the Board of Trustees accepted from Duncan Phillips, a Trustee of the Gallery, the gift of a portrait of

former Chief Justice Hughes, first Chairman of the Board, painted by Augustus Vincent Tack, which has been hung in the Board Room.

On February 9, 1942, the Board accepted from Mrs. Ralph Harman Booth, the gift of the following pieces of sculpture, given in memory of her husband:

Greek (fourth century B. C.)	Head of a Youth.
Middle Rhenish School	Pieta.
Nottingham School	Painted alabaster, Christ supported by an Angel.

On April 27, 1942, the Board of Trustees accepted from Mr. and Mrs. George W. Davison the gift of a portrait of George Washington by Rembrandt Peale.

Also, on April 27, 1942, the Board accepted from Mrs. Gordon Dexter the gift of two paintings by John Singleton Copley:

Red Cross Knight
Portrait of Sir Robert Graham

The paintings have been received and are now on exhibition.

On April 27, 1942, the Board accepted from Mrs. John W. Simpson the gift of a group of paintings, drawings, and sculpture. Included in the gift are two paintings, one entitled "Soap Bubbles," by Jean-Baptiste-Simeon Chardin, and the other, "The Binning Children," by Sir Henry Raeburn, the latter presented in memory of the late John Woodruff Simpson. The 11 drawings and 13 pieces of sculpture by Auguste Rodin constitute a unique collection acquired by the donor some 40 years ago directly from the artist. The Clodion terracotta plaque also served as a model for the decoration of one of the monumental urns by Clodion now in the Gallery.

SALE OR EXCHANGE OF WORKS OF ART

During the year no works of art belonging to the Gallery were sold or exchanged.

LOAN OF WORKS OF ART TO THE GALLERY

During the year the following works of art were received on loan:

From Copley Amory of Washington, D. C.:

Artist	*Subject*
John Singleton Copley	The Copley Family
Do	Self-portrait
Do	Portrait of Elisabeth Copley
Henry William Pickersgill	Portrait of John Singleton Copley, Jr.
John Singleton Copley	Red crayon drawing of a hand

From Chester Dale, of New York, 126 important paintings of the French nineteenth-century school and other schools of painting, together with 31 French drawings.

Through the French Government from museums and private collectors in Europe, 154 paintings of the French school of the late eighteenth and nineteenth centuries. In addition, this loan has been supplemented by 101 French drawings which have not yet been placed on exhibition.

From the heirs of the late Right Reverend William Lawrence a portrait of their ancestor, Amos Lawrence, by Chester Harding.

From the J. H. Whittemore Co., of Naugatuck, Conn., 24 French and American paintings from the Harris Whittemore collection. The following paintings from the collection have been placed on exhibition:

Artist	*Subject*
Edgar Degas	The Rehearsal
Auguste Renoir	Nude in Landscape
Do.	Girl with a Cat
J. A. McN. Whistler	The White Girl
Do.	The Sea
Do.	L'Andalusienne

LOAN OF WORKS OF ART RETURNED

During the year the following works of art which had been placed on loan at the Gallery were returned:

To Duncan Phillips, a Trustee of the Gallery, two paintings previously loaned by him:

Artist	*Subject*
Camille Corot	The Dairy Farm
Gustave Courbet	Rocks at Ornans, Afterglow

LOAN OF WORKS OF ART BY THE GALLERY

During the year no works of art, belonging to the Gallery, were placed on loan.

EXHIBITIONS

The following exhibitions were held at the National Gallery during the last year:

An exhibition, entitled "The Great Fire of London, 1940," of 107 paintings and drawings of wartime London by artists serving in the London Auxiliary Fire Service, was shown in the Gallery from July 18 through August 10, 1941. Sponsored by the British Government under the auspices of the British Library of Information, this exhibition—selected by Sir Kenneth Clark, Director of the National Gallery, London; Sir Walter W. Russell, R. A., Keeper of the Royal Academy; and J. B. Mason, former Curator of the Tate Gallery, London—after the completion of its first showing in the United States at the National Gallery, toured the United States and Canada.

Seventy paintings and drawings, and sculpture, representing the art of Australia from 1788 to 1941, were placed on exhibition at the

Gallery from October 2 to 26, 1941. These works of art, the first comprehensive exhibition of Australian art to be shown in the United States, were sent, under the auspices of the Carnegie Corporation of New York, by the Commonwealth of Australia.

Architectural drawings of the National Gallery building, together with progress photographs and a model of the exterior of the building, showing the development of the building from the first sketch to the final drawings, were loaned by Eggers & Higgins, the architects, for exhibition at the Gallery from December 18, 1941, to January 28, 1942. The A. W. Mellon Educational and Charitable Trust, to augment the exhibition, loaned a number of renderings and photographs of the progress of the building from their own records.

Two groups of American water colors, drawings and prints—"American Artists' Record of War and Defense" and "Soldiers of Production"—were shown at the National Gallery; the former from February 7 to March 8, 1941, and the latter from March 17 to April 15, 1942. The water colors in the first group had been submitted in national competition for pictures recording war and defense activities, conducted by the Section of Fine Arts for the Office for Emergency Management, and most of them were purchased by the United States Government after selection by the appointed jury. Those in the second group were water colors and drawings by eight artists appointed on recommendation of the Section of Fine Arts by the Office for Emergency Management and who, through the courtesy of the War and Navy Departments, were permitted to make drawings and paintings of what is known as restricted material.

The Citizens Committee for the Army and Navy, Inc., exhibited at the Gallery for a period of approximately 2 weeks, beginning April 8, 1942, three triptychs by contemporary artists, which had been selected by the Committee for later presentation to the Chapel at Arlington Cemetery, Va.

An exhibition of paintings, posters, water colors, and prints, showing activities of the American Red Cross, were exhibited from May 2 to 30, 1942. These paintings were submitted in a national competition conducted for the American Red Cross by the Section of Fine Arts, Public Buildings Administration, Federal Works Agency. The exhibition included the paintings which were purchased for the Red Cross on advice of a jury, together with a group of other pictures also recommended by the jury for exhibition.

An exhibition of 11 portrait busts of the Presidents of the Republics of South America, by the American sculptor, Jo Davidson, was held in the west garden court at the National Gallery of Art, beginning Saturday afternoon, June 27, and continuing for about a month. These busts were commissioned by the Office of the Co-

ordinator of Inter-American Affairs and will be presented to the Governments of the South American Republics by the Department of State of the United States of America. Portrait busts in bronze, also by Jo Davidson, of President Franklin Delano Roosevelt and Vice President Henry A. Wallace, were shown at this time.

CURATORIAL DEPARTMENT

The curatorial work for the year consisted in the rearrangement of the permanent collection necessitated by additional gifts and by various precautions that were required by the outbreak of the war; in the installation of 17 temporary exhibitions; in various lectures on the collection and related fields in conjunction with the work of the educational department; and in further cataloging of the paintings and sculpture. During the year the preliminary Catalog of the Permanent Collection and the Book of Illustrations were brought up to date and reprinted; two catalogs containing a historical survey, notes, and bibliography of the French paintings loaned from the Chester Dale collection were compiled, and a new general information pamphlet was prepared.

In the course of the year, 209 works of art were submitted to the acquisitions committee with written recommendations regarding their acceptability for the collection of the National Gallery of Art; 40 private collections were visited in Washington and other cities in connection with offers to the Gallery of gifts or loans; 152 works of art were brought to the Gallery and submitted to the staff for expert opinion; and 44 letters were written in answer to inquiries involving research in the history of art.

RESTORATION AND REPAIR OF WORKS OF ART

During the year, as authorized by the Board and with the approval of the Director and Chief Curator, Stephen Pichetto, consultant restorer to the Gallery, has undertaken such restoration and repair of paintings and sculpture in the collection as has been found to be necessary. All of this work was carried on in the restorer's rooms in the Gallery except in three cases, once when unusually delicate and complicated restoration was required, and twice when the pictures had to be relined to prevent damage in shipment from New York. These three paintings were restored in Mr. Pichetto's studios in New York.

EDUCATIONAL PROGRAM

As indicated in the following summary, public response to the program of educational activities of the Gallery has constantly increased month by month until the total attendance recorded for

June, 1942 (6,384), more than doubled that recorded for July, 1941 (2,882).

A basic part of the Gallery's educational program has been the gallery tours of the collection, conducted twice daily, except on Saturday and Sunday, which have attracted 18,935 visitors. In addition to these tours there has been a series of special lectures: a special program of 34 lectures, beginning in October and continuing through April, presented a special lecture each Saturday afternoon in the lecture hall, which 7,292 persons attended, and the intimate "gallery talks" and other lectures presented in the auditorium, dealing with a specific school or works of art, attracted a combined total of 17,752.

The educational department feeling the need for a short noontime feature, in view of the increased number of visitors from nearby Government buildings during this time, inaugurated on January 2, 1942, the "Picture of the Week," a 15-minute talk given twice each day and once on Sunday, which in turn attracted 7,947 people, indicating that this educational feature of the program was one of the most popular.

In addition, members of the educational department staff have conducted private and group conferences, totaling 3,065 individuals, of which 700 were members of the armed forces for whom special tours were arranged on Saturday afternoon, beginning in December 1941.

LIBRARY

A total of 242 books and 1,087 pamphlets and periodicals were presented to the Gallery; 962 books and catalogs were acquired through exchange; 37 books and catalogs were purchased; and 20 books were received on indefinite loan.

PHOTOGRAPHIC DEPARTMENT

Prints totaling 6,094, 1,187 black and white slides, and 709 color slides have been made by the photographic laboratory. The prints have been placed on file in the Library where they are for sale and for the use of the Gallery staff. The slides, together with an additional 420 which were purchased during the year, have been made available for the staff in connection with the public lectures given at the Gallery, and have likewise been lent to lecturers outside the National Gallery and to other galleries.

THE GALLERY BUILDING

During the fiscal year, certain alterations and improvements have been made in the building upon the recommendation of the committee on the building, among which may be mentioned the construc-

tion of snow steps for the Mall entrance, the redecoration of gallery rooms for the exhibition of the Chester Dale collection, and additional air conditioning in the smoking room and the information rooms on the main and ground floors. The National Gallery Cafeteria has become so popular that it is somewhat congested during certain hours of the day. It became evident that some acoustical treatment of the ceiling should be undertaken, and this work, resulting in great improvement in the noise condition in the cafeteria, was completed with funds supplied by The A. W. Mellon Educational and Charitable Trust. It was also recommended that a revolving door be installed to replace one of the heavy bronze doors at the Constitution Avenue entrance. Although funds were made available it was not possible to proceed with this improvement because the materials required were restricted by priority rulings.

OTHER GIFTS

During the year there were gifts to the Gallery of furnishings, equipment, ornamental trees and plants, prints, films, and color slides; also certain expenses were paid by others on behalf of the Gallery, the donors being David K. E. Bruce, Frederick T. Bonham, William R. Coe, David E. Finley, Samuel H. Kress, Donald D. Shepard, Percy S. Strauss, Mr. and Mrs. J. L. McGrew, Mrs. Matthew John Whittall, Coordinator of Inter-American Affairs, Propagating Gardens of the Department of the Interior, American Red Cross, and The A. W. Mellon Educational and Charitable Trust. Gifts of moneys were made to the Gallery during the year by Paul Mellon, Chester Dale, Howard J. Heinz, Jr., and The A. W. Mellon Educational and Charitable Trust.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

An audit has been made of the private funds of the Gallery for the year ended June 30, 1942, by Price, Waterhouse & Co., a nationally known firm of public accountants, and the certificate of that company on its examination of the accounting records maintained for such funds has been submitted to the Gallery.

Respectfully submitted.

David K. E. Bruce, *President.*

Dr. C. G. Abbot,
Secretary, Smithsonian Institution.

APPENDIX 3

REPORT OF THE NATIONAL COLLECTION OF FINE ARTS

SIR: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1942:

After Pearl Harbor plans were made for the protection of the works of art in the National Collection of Fine Arts. The center portion of the wall behind the large painting "Diana of the Tides," by John Elliott, was strengthened sufficiently to resist bomb fragments. Protection against damage from incendiary bombs has been provided, but means have not yet been devised to prevent such bombs from reaching the ground floors where the exhibits are shown. Plans for packing and shipping paintings for evacuation have been made, and the miniatures and part of the Gellatly collection are to be moved to the ground-floor lobby, where they would be protected against incendiary bombs.

Several proffered gifts of paintings, furniture, miniatures, and vases have been deposited here to be passed upon by the Smithsonian Art Commission in December 1942.

Eight special exhibitions were held in the foyer, including three under the sponsorship of the Pan American Union and the Ministers of the various countries, involving the installation of 428 specimens. Nine special Graphic Arts exhibits were shown in the lobby.

From July 10 to 27, 1941, the Acting Director visited galleries and private collections between Washington and Boston for the purpose of studying various collections of American miniatures.

An illustrated lecture on the National Collection of Fine Arts was given by the Acting Director before the Chevy Chase Women's Club on November 11, 1941.

A painting, "The First Reading of the Emancipation Proclamation," by Francis B. Carpenter, 9 feet x 14 feet 6 inches, was cleaned and restored at the United States Capitol.

APPROPRIATIONS

For the administration of the National Collection of Fine Arts by the Smithsonian Institution, including compensation of necessary employees, purchase of books of reference and periodicals, traveling

expenses, uniforms for guards, and necessary incidental expenses, $29,880.14 was appropriated, of which over $18,000 was expended for the care and maintenance of the Freer Gallery of Art, a unit of the National Collection of Fine Arts. The balance was spent for the care and upkeep of the National Collection of Fine Arts, nearly all of this sum being required for the payment of salaries, traveling expenses, purchase of books and periodicals, and necessary disbursements for the care of the collection.

THE SMITHSONIAN ART COMMISSION

The twenty-first annual meeting of the Smithsonian Art Commission was held on December 2, 1941. The members met at 10:30 a. m. in the Natural History Building, where, as the advisory committee on the acceptance of works of art which had been submitted during the year, they accepted the following:

Oil painting, "Portrait of My Wife," by Louis Betts, N. A. Gift of Mrs. Louis Betts (Zara Symons Betts).

Oil painting, "Stable Interior, Horses and Groom," by John F. Herring (1795–1865). Gift of John E. Lodge.

Oil painting, "Portrait of Lieut. Gen. Henry Clark Corbin (1842–1909)," by Adolph Muller-Ury (1868–). Gift of Mrs. Henry Clark Corbin.

Oil painting, "The Other Shore," by Robert Spencer, N. A. (1879–1931), assigned to the Newark Museum Association, Newark, N. J., on February 2, 1925, by the Council of the National Academy of Design, which was withdrawn and claimed in accordance with the provision in the Ranger Bequest.

Three miniatures, water color on ivory, "Portrait of A. S. N.," by Jean Francois de la Valle (fl. 1785–1815); "Portrait of Mrs. Elves," attributed to Hone, and "Portrait of Ira Allen (1751–1814)," copy of a miniature in the University of Vermont, by an unknown artist. Gift of Mrs. Norvin H. Green.

Miniature, water color on ivory, "Portrait of Mrs. Bertha E. Jaques (1863–1941)," by Nelly McKenzie Tolman. Bequest of Mrs. Bertha E. Jaques.

Miniature, water color on paper, "Portrait of Rubens Peale (1784–1864)," by Raphael Peale (1774–1825), unframed. Gift of Dr. Edwin Kirk.

Thirty-six prints by 28 members of the Chicago Society of Etchers, to be added to the Chicago Society of Etchers collection. Gift of the Chicago Society of Etchers.

Drypoint, "For All the World," by R. H. Palensky (1884–), to be added to the Chicago Society of Etchers collection. Gift of the artist.

One Japanese Shippo vase and stand. Gift of Dr. and Mrs. H. Foster Bain.

The members then proceeded to the regents' room in the Smithsonian Building for the further proceedings, the meeting being called to order by the chairman, Mr. Borie.

The members present were: Charles L. Borie, Jr., chairman; Frank Jewett Mather, Jr., vice chairman; Dr. Charles G. Abbot (ex officio), secretary; and Herbert Adams, Gifford Beal, David E. Finley, James E. Fraser, John E. Lodge, Paul Manship, Edward W. Redfield, and Mahonri M. Young. Ruel P. Tolman, curator of the division of

graphic arts in the United States National Museum and acting director of the National Collection of Fine Arts, was also present.

Three persons were nominated to succeed the late Col. George B. McClellan, and the secretary was directed to correspond with them in the order they were nominated to ascertain their willingness to serve as a member of the Commission.

The Commission recommended to the Board of Regents the reelection of Mahonri M. Young, Charles L. Borie, Jr., Frederick P. Keppel, and the nominee selected to fill Colonel McClellan's place.

The following officers were reelected for the ensuing year: Charles L. Borie, Jr., chairman; Frank Jewett Mather, Jr., vice chairman, and Dr. Charles G. Abbot, secretary.

The following were reelected members of the executive committee for the ensuing year: Herbert Adams, Gilmore D. Clark, John E. Lodge, Charles L. Borie, Jr. (ex officio), and Dr. Charles G. Abbot (ex officio).

The chairman brought to the attention of the Commission the matter of the proposed prohibition of the use of sculptural bronze for castings and, after discussion, resolutions were approved to be sent to the Office of Production Management.

THE CATHERINE WALDEN MYER FUND

Three miniatures, water color on ivory, were acquired from the fund established through the bequest of the late Catherine Walden Myer, as follows:

25. "Portrait of G. D.," by an unknown artist; from Sherman Reilley, New Haven, Conn.
26. "Portrait of a Man," by an unknown artist; from Sherman Reilley, New Haven, Conn.
27. "Mr. Nichol," by John Wesley Jarvis (1780–1840), signed "Jarvis 1809 N York"; from Mrs. Dora Lee Curtis, New York City.

LOANS ACCEPTED

Two miniatures, water color on ivory, "Roswell Shurtleff (1773–1861)" and "Anna Pope Shurtleff (1812–1881)," daughter of Roswell Shurtleff, by unknown artists, were lent by Mrs. O. A. Mechlin, through Miss Leila Mechlin.

One miniature, water color on ivory, "Captain Frederick Augustus Smith, U. S. A. (1812–?)," by Caroline Dorcas (Smith) Murdoch, was lent by Miss Leila Mechlin.

One miniature, water color on ivory, "Portrait of a Boy," by Joseph Wood (ab. 1780–1830), was lent by Miss Sarah Lee.

An oil painting, "The Right Honorable Winston Churchill," by Hal Denton, presented to the President of the United States by the

Mayor and the Council of Vancouver, British Columbia, Canada, was lent by the President of the United States, Franklin D. Roosevelt.

LOANS TO OTHER MUSEUMS AND ORGANIZATIONS

An oil painting, "The Visit of the Mistress," by Winslow Homer, was lent to the Howard University Gallery of Art to be included in an exhibition of "Paintings Showing Negroes in America" from March 2 through April 12, 1942. (Returned April 17, 1942.)

WITHDRAWALS BY OWNERS

An oil painting, "Portrait of Mr. Justice Brandeis," by Joseph Tepper, was withdrawn on the order of Paul A. Freund and returned to Joseph Tepper, the owner, on November 3, 1941.

An oil painting, "Portrait of Lady Evelyn Cook," by John Hoppner, R. A., was withdrawn by Thomas Davis Lee, administrator of the estate of Mrs. Arthur Lee, on February 13, 1942.

Three oil paintings, "Portrait of a Boy," by John Hoppner, R. A.; "Portrait of a Girl," by John Opie, R. A.; and "Study of Ruins," by Richard Wilson, R. A., were withdrawn from the collection lent by the estate of Henry Cleveland Perkins by the owner, Miss Ruth Perkins, on March 12, 1942.

Two miniatures, water color on ivory, "Virginia Casterton" and "Mme. Tamakai Miura," by Eda Nemoede Casterton, were withdrawn by the owner, Mrs. Casterton, on May 26, 1942.

LOANS RETURNED

Three pieces of sculpture by Edward Kemeys, "Fighting Panther and Deer" (bronze), "Bronze Wolf" (No. 3), and "Bronze Wolf" (No. 4), lent with the consent of their owner, William Kemeys; "Grizzly Bear" (plaster No. 28), the property of the Smithsonian Institution, and a blue Sevres vase (Pell Collection No. 371), with a wooden base, lent to the Procurement Division of the United States Treasury on May 2, 1938, to be placed in the Reception Room, Union Station, were returned December 18, 1941.

THE NATIONAL COLLECTION OF FINE ARTS REFERENCE LIBRARY

Because of the transfer of the librarian, Mrs. Lucile T. Barrett, to Mobile, Ala., in February 1942 there is no report of details available, as a new librarian has not been appointed.

SPECIAL EXHIBITIONS

The following exhibitions were held:

August 1 through September 30, 1941.—Exhibition of 92 miniatures lent by Count and Countess Bohdan de Castellane, of Washington, D. C.

December 5 through 31, 1941.—Exhibition of 23 oils and 20 water colors by Roy M. Mason, N. A., of Woodchuck Hollow, Batavia, N. Y.

January 7 through 31, 1942.—Exhibition of 26 oils and 38 prints and drawings, by Antonio Rodriguez Luna, of Mexico, sponsored by the Mexican Ambassador and the Pan American Union.

January 15 through March 1, 1942.—Exhibition of 54 pieces of jade lent by Georges Estoppey, of Newark, N. J.

February 8 through 27, 1942.—Exhibition of 20 paintings on metal and 4 prints by Buell Mullen of Lake Forest, Ill.

April 5 through 28, 1942.—Exhibition of 80 oils, 36 water colors and 5 prints, by members of the Landscape Club of Washington, D. C.

May 12 through 28, 1942.—Exhibition of 15 plaster busts by Marina Nuñez del Prado of Bolivia, sponsored by the Bolivian Minister and the Pan American Union.

June 1 through 28, 1942.—Exhibition of 17 oil paintings and 37 pencil drawings, lithographs, and water colors, by Ignacio Aguirre, of Mexico, sponsored by the Mexican Ambassador and the Pan American Union.

PUBLICATIONS

TOLMAN, R. P. Report on the National Collection of Fine Arts for the year ended June 30, 1941. Appendix 3, Report of the Secretary of the Smithsonian Institution for the year ended June 30, 1941, pp. 45-50.

LODGE, J. E. Report on the Freer Gallery of Art for the year ended June 30, 1941. Appendix 4, Report of the Secretary of the Smithsonian Institution for the year ended June 30, 1941, pp. 51-55.

Respectfully submitted.

R. P. TOLMAN, *Acting Director.*

Dr. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the twenty-second annual report on the Freer Gallery of Art for the year ended June 30, 1942.

THE COLLECTIONS

Additions to the collections by purchase are as follows:

BRASS

42.8. Persian, dated 1127 (A. D. 1715). Made by 'Abd-al-A'immah. Astrolabe. A northern instrument fitted with a ring and handle for suspension, a *rete* or *'ankabût*, three sexpartite tablets, an alidade equipped with sights, a pin and a bolt. Inscriptions, including signature, in *naskhi* script. Diameter: 0.129.

41.10 Syrian (Damascus?), mid-thirteenth century. Mōṣul school. A canteen with a pit in one side and a strainer in the neck. The outer surfaces are decorated with designs of both Christian and Islamic origin executed in silver inlay, and include inscriptions written in Kufic and in *naskhi* scripts. Height: 0.447; diameter: 0.365; depth: 0.213.

BRONZE

41.9. Chinese, late Chou dynasty, circa 500-300 B. C. A large bell, with two confronted bird forms on the top. Decoration in slight relief, details incised. Gray-green patination. 0.663 x 0.470 over all.

42.1. Chinese, early Chou dynasty, twelfth-eleventh century B. C. A ceremonial vessel of the type *huo*, with a cover in the form of a human face with horns. Patination: outside, gray green with sparse malachite incrustations; inside, gray, gray-green, malachite, cuprite, azurite, and calcareous deposit. 0.182 x 0.210 over all. (Illustrated.)

JADE

42.6. Chinese, early Chou dynasty or earlier. A pointed implement for loosening knots; pierced for suspension. Somewhat translucent pale gray-green nephrite with pale tan mottling. The handle carved in silhouette and countersunk linear relief to represent a long-haired human figure seen in profile. Length: 0.106 over all.

MANUSCRIPT

42.3-42.4. Arabic, thirteenth century. Two leaves from a *Qur'ân*. The text is written in *naskhi* script, which is drawn in black outline and filled

COVER 42.1

42.1

A RECENT ADDITION TO THE COLLECTION OF THE FREER GALLERY OF ART.

41.12

42.2

RECENT ADDITIONS TO THE COLLECTION OF THE FREER GALLERY OF ART.

in with gold; vowels and orthographical signs in blue and (occasional) red. Illuminated verse-stops and marginal ornaments. Paper leaves: 0.435 x 0.345.

PAINTING

42.10. Arabic (Northern Mesopotamia), A. D. 1315. Âmidn. An illustration from a copy of al-Jazari's treatise on automata, *Kitâb fî ma'arifat al-ḥiyal al-handasiya:* the face of the water clock called "The Clock of the Drummer." Painted in full color and gold; text in black *naskhi* script. Paper leaf: 0.308 x 0.215. (One of a set: 30.71–77, 42.10.)

42.7. Chinese, Ming dynasty. By Ni Yüan-lu (1593-1644). Six flower sprays. Ink on paper. Seven inscriptions, 10 seals. Signature. Makimono: 0.269 x 3.136.

42.11–42.12. Persian, thirteenth–fourteenth century. Two leaves from a *Shâhnâmah* with illustrations painted in color and slight gold as follows:

42.11. Rustam confronting the Turanian, Pilsam; horsemen on a red ground. 0.090 x 0.240.

42.12. Kai Khusraw crossing the water of Zirih. 0.133 x 0.241.

Text in a delicate *naskhi* script. Paper leaves (trimmed): 0.370 x 0.303; 0.370 x 0.301.

42.2. Persian, Mongol (Îl-Khân) period, fourteenth century. Tabriz school. An illustration from a *Shâhnâmah:* Shâh Nûshîrwân bestows largess upon his minister Bûzurjmihr. Painted in full color and gold. Text in black *naskhi* script, titles in gold on blue and red grounds. Paper leaf: 0.412 x 0.295; painting: 0.185 x 0.196. (One of a set: 23.5, 30.78, 30.79, 35.23, 35.24, 38.3, 42.2.) (Illustrated.)

POTTERY

41.12. Arabic (Egypt) tenth–eleventh century (?). Fatimid period. A large, wide-rimmed dish; bold foot-ring (broken, repaired and, in places, restored). Body of soft, white clay, covered with an opaque cream-white glaze. Decoration painted in gold luster with iridescent reflections. Kufic inscriptions; potter's mark underneath. 0.383 (diameter). (Illustrated.)

42.5. Mesopotamian, Raḳḳa twelfth-thirteenth century. A shallow bowl with broad everted rim; bold foot-ring (one perforation). Soft, sandy, white clay covered with a transparent, greenish-white glaze; areas of pearly iridescence due to decay. Decoration painted over glaze in golden-brown luster; four spots of turquoise blue. Two *naskhi* inscriptions, one partly lost under iridescence. 0.075 x 0.259 (diameter).

41.11. Persian, dated 607 (A. D. 1210). Kâshân. Signed by Sayyid Shams-ud-din al-Ḥasanî. A plate with scalloped, upright sides and a narrow, grooved rim (broken, repaired and, in places, restored). Body of soft white clay covered with an opaque, cream-white glaze. Decoration painted in golden-brown luster with ruby reflections. Marginal inscription, including the signature and date. 0.037 x 0.352 (diameter).

42.9. Syro-Egyptian, thirteenth century (?). A deep bowl (broken and repaired). Body of soft rosy-buff clay covered with a white slip under a transparent glaze of greenish cast (crazed). Decoration painted in brown on the slip under glaze. 0.080 x 0.194.

The work of the curatorial staff has been devoted to the study and recording of the new acquisitions listed above, and to other Arabic, Chinese, Japanese, Persian, Syrian, and Syro-Egyptian art objects either already in the collection or submitted for purchase. Other Arabic, Chinese, East Indian, Japanese, Persian, European, and American objects were sent or brought to the Director by their owners for information as to identity, provenance, quality, date, or inscriptions. In all, 770 objects and 235 photographs of objects were so submitted, and written or oral reports upon them were made. Written translations of 41 inscriptions in oriental languages were made upon request. In addition to this regular curatorial work, much time during the winter and spring has been spent by members of the staff upon work connected with the war.

Two hundred and thirty-six changes were made in exhibition as follows:

American painting	3
American pottery	7
Chinese bronze	129
Chinese gold and iron	4
Chinese silver	2
Chinese silver-gilt	6
Chinese pottery	12
Japanese painting	48
Japanese pottery	24
Syrian brass and silver	1

Repairs to the collection were as follows:

American paintings	15
Chinese bronze	1
Chinese panel painting	1
Chinese jade	1
Japanese screens	3

A scale model of a Japanese print-maker's workshop was made for the Division of Graphic Arts, Smithsonian Institution.

ATTENDANCE

The Gallery has been open to the public every day from 9 until 4:30 o'clock, with the exception of Mondays, Christmas Day and New Year's Day.

The total attendance of visitors coming in at the main entrance was 87,812. Seventy-eight other visitors on Mondays bring the grand total to 87,890. The total attendance on weekdays, exclusive of Mondays, was 57,240; Sundays 30,572. The average weekday attendance was 222 persons; the average Sunday attendance 588. The highest monthly attendance was in August with 13,055 visitors; the lowest in January with 4,417 visitors.

There were 1,223 visitors to the main office during the year. The purposes of their visits were as follows:

For general information	214
To see objects in storage	234
Far Eastern paintings	31
Near Eastern paintings and manuscripts	7
East Indian paintings and manuscripts	12
American paintings	41
Whistler prints	2
Oriental pottery, jade, bronzes, sculpture, lacquer and bamboo	89
Byzantine objects	2
Washington Manuscripts	50
To read in the library	180
To make tracings and sketches from library books	7
To see the building and installation	8
To obtain permission to photograph or sketch	26
To submit objects for examination	141
To see members of the staff	368
To see the exhibition galleries on Monday	19
To examine or purchase photographs	280

LECTURES AND DOCENT SERVICE

One lecture by a staff member was given to a woman's club organization (20 members); 5 groups (total 81 persons) were given instruction in the study room; 1 group (20 persons) was given docent service in storage rooms, and 9 groups (total 190 persons) were given docent service in the exhibition galleries. The total number of persons receiving such services, by request, was 311.

A series of lectures upon air-raid precautions, addressed to Smithsonian and Freer Gallery employees, was given in the auditorium by Kenneth M. Perry of the United States National Museum, June 9, 11, and 13, 1942; total attendance, 97.

PERSONNEL

Grace T. Whitney worked intermittently at the Gallery from November 3, 1941, to June 22, 1942, on the translation of Persian texts.

On March 7, 1942, Margaret B. Arnold resigned as assistant after 2 years of service.

Miss M. Eleanor Morsell was appointed to succeed Miss Arnold on May 1, 1942.

On June 16, after a month's serious illness, occurred the death of Carl Whiting Bishop, associate in archeology. Mr. Bishop became a member of the Gallery staff April 10, 1922, to work in his chosen field of Far Eastern archeology. From 1923 to 1927, and again from

1929 to 1934, Mr. Bishop was in charge of the Freer Gallery field work in China, making reconnaissance studies at neolithic stations in Shansi Province as well as general surveys of burial sites of the historic period. He published numerous articles upon these subjects in various journals, being widely known as an authority on the earlier phases of Chinese culture. His death, at 61, is a matter of deep regret to his colleagues.

Other changes in personnel are as follows:

Appointments: Glen P. Shephard, guard, July 30, 1941; Edith B. Bauer, attendant (intermittent), October 19, 1941; Thomas J. Reynolds, guard, January 14, 1942; V. Lee Turner, attendant (intermittent), February 1, 1942; Florence E. James, attendant (intermittent), May 3, 1942; Alice E. Hall, charwoman, May 7, 1942; Frank M. Murphy, guard, June 6, 1942; Milton V. Harper, attendant (intermittent), June 21, 1942.

Separations from the service: Mary C. Burke, attendant (intermittent), resigned October 1, 1941; Joseph P. Germuiller, guard, retired from active duty December 8, 1941; George W. Grigsby, attendant (intermittent), resigned January 26, 1942; V. Lee Turner, attendant (intermittent), resigned February 27, 1942; James Rice, attendant (intermittent), resigned March 15, 1942; Ollie Smoot, charwoman, resigned March 17, 1942; Edith B. Bauer, attendant (intermittent), resigned April 15, 1942; Oliver W. Puckett, guard, resigned May 26, 1942; Thomas J. Reynolds, guard, resigned June 30, 1942.

Respectfully submitted.

J. E. Lodge, *Director.*

Dr. C. G. Abbot,

Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1942, conducted in accordance with the act of Congress of April 5, 1941, which provides "* * * for continuing ethnological researches among the American Indians and the natives of Hawaii and the excavation and preservation of archeologic remains. * * *"

During the fiscal year, the energies of the Bureau have been diverted to an increasing extent to activities concerned with the war effort. In particular, members of the Bureau staff have cooperated with the Ethnogeographic Board, and it is expected that diversion of effort in this direction will increase as the war continues. Activities concerned with Latin America have likewise been emphasized.

SYSTEMATIC RESEARCHES

M. W. Stirling, Chief of the Bureau, left Washington for Mexico early in April 1942 in continuation of the program of work for the Smithsonian Institution-National Geographic Society archeological project in southern Mexico. A visit of 2 weeks was made to the site of La Venta in Tabasco, where Dr. Philip Drucker was conducting excavations on the same project. From La Venta, Mr. Stirling went to Tuxtla Gutierrez in Chiapas in order to attend the archeological conference held under the sponsorship of the Sociedad Mexicana de Antropología. While in Chiapas opportunity was taken to visit villages of the Zoque, Tzotzil, and Chamula Indians. A trip was also made to the ancient Maya ruins of Palenque, where a week was spent at the site. Mr. Stirling returned to Washington early in June.

The remainder of the year was spent in Washington administering the affairs of the Bureau and in the preparation of reports dealing with the work in Mexico.

Dr. John R. Swanton, ethnologist, devoted the greater part of the fiscal year to digesting and carding the extant materials in the language of the Timucua Indians of Florida, a language which passed out of existence early in the eighteenth century. He also devoted some time to the revision of a large general paper on the Indians of North

America. This manuscript has not been submitted for publication as, owing to its size, there is little likelihood of its being printed in the near future. A brief paper was prepared on The Evolution of Nations, and this was published in the series of War Background Studies of the Smithsonian Institution.

Dr. Swanton has also continued to serve as the representative of the Institution on the United States Board of Geographical Names.

Dr. John P. Harrington, ethnologist, conducted field work during the year on two problems involving linguistic studies of Aleut, the language of the islands between Asia and America, and of Athapascan, the language of the northern Rockies, of a large part of the Pacific coast, and of the southern deserts. He left Washington in August 1941 to visit the Aleutian Islands, where he was fortunate enough to secure the services of Ivan Yatchmeneff, son of the Unalaska chief. The Aleuts consist of three divisions, popularly known as Unalaskans, Atkans, and Attuans, but all of them are under the Unalaska chief. Working on St. Paul Island, famous as the breeding place of the fur seal, and elsewhere, he made a complete study of the sounds and grammar of the language, with the result that it proved to be a penetrant from the American side, a typically American language of eastern origin, which has penetrated westward never quite to cross the Aleutian Chain. The Unalaska dialect is related to and undoubtedly derived from the language of the Alaska peninsula. The fact that the Chain was occupied by an American language is important because of its possible fundamental relationship to the Athapascan stock of inland Alaska.

A byproduct of the field studies was the obtaining of a probable etymology of the name "Aleut" which differs from those previously offered by other investigators. The name is still pronounced with three syllables in Russian, as Al-e-ut, and is the same as the tribal name "Aglimyut," in modern usage applied to a Bristol Bay tribe. The name of the high hill on St. George Island also omits the interior *m*, just as it is omitted in the word "Aleut." Early Russian usage took over the name with inclusive application, which later became crystallized into application to speakers of the Aleut language alone, although the Kodiak Islanders are still spoken of in Russian and Aleut as the Kodiak Aleuts, even at the present day.

Following the Aleutian work, Dr. Harrington proceeded to British Columbia, where he undertook studies of the relationship of Navaho and Apache with the Athapascan stock of the northernmost Rocky Mountains. This relationship was first reported by Horatio Hale and by William Turner. In British Columbia Dr. Harrington recovered traditions that the Chilcotin language had formerly occupied the Nicola Valley, and was able to obtain a large number of Chilcotin words in that region, handed down in individual families. Following

this lead, he was able to discover individuals who had in their remote youth actually spoken the extinct Kwalhioqua and Tlatskanai dialects of Washington and Oregon, and to recover vocabularies of these with all their original phonetics. He also recorded the tradition that the Upper Umpqua language of what is now the vicinity of Roseburg, Oreg., had come from the Kwalhioqua. The Roseburg language is related to the languages of the Rogue River region of southern Oregon and those of northern California. In confirmation of these findings, he obtained the tradition that the Blue Lake Indians had come from the south bend of the Smith River, far to the north. Dr. Harrington has traced the Chilcotin or Chilco language all the way from Lake Chilcotin, which drains into the Fraser River, to the head of Eel River in northern California. This work has demonstrated that the Eel River language is merely a Chilco dialect which has drifted south. The exact provenience of these southern tongues is Dr. Harrington's present goal.

At the beginning of the fiscal year Dr. Frank H. H. Roberts, Jr., was engaged in archeological excavations at a site on the north rim of the Staked Plains, 10½ miles south of the town of San Jon, N. Mex. These investigations were continued until September 6. The work produced evidence for an interesting sequence of projectile points and other artifact types and new information on some phases of the aboriginal occupation of that portion of the Southwest. The oldest archeological material present was found to be in association with bones from an extinct species of bison and in the same stratum as mammoth remains. Indications are that, although from a different complex, this material probably dates from about the end of the Folsom horizon some 10,000 to 15,000 years ago. Between this level and the next in the series there was a gap of an, as yet, undetermined although appreciable length of time. During this interval the large bison were replaced by a smaller species, the modern buffalo. From the start of the second stage down to protohistoric times there was no break in the occupation of the area investigated, and the points and artifacts were found to progress from forms similar to those found in the Texas area to the east to those commonly associated with late sites in many parts of the country. The specimens from the second level belong to the so-called Yuma category, and the evidence from San Jon indicates that chronologically they are much later than hitherto supposed. The artifacts from the late horizon show that several different Indian groups used that area as hunting territory. In the light of present knowledge, however, it is not possible to identify the specific groups from the artifact types.

In keeping with the Smithsonian Institution's policy of cooperation with and aid to other institutions, Dr. Roberts took leave from July 28 to August 9 to give a series of lectures on Southwestern archeology and to direct student excavations at the University of New Mexico Field Session in the Chaco Canyon, N. Mex. During his absence, the work at San Jon was continued under the supervision of Eugene C. Worman, Jr., of the department of anthropology, Harvard University. From the Chaco Canyon, Dr. Roberts returned to San Jon, and, upon completion of the work there, returned to Washington.

The fall and winter months were spent in regular office routine; in the preparation of a manuscript entitled "Archeological and Geological Investigations in the San Jon District, Eastern New Mexico" for publication in the Smithsonian Miscellaneous Collections; in library researches for information for and sponsoring programs on Carthage, Zebulon M. Pike, and Babylon for "The World Is Yours" broadcasts; in organizing air-raid protection groups for the Smithsonian building and serving as building warden under the Public Buildings Administration Civilian Defense program; and in assisting in the preparation of material for evacuation to storage places outside of Washington.

On June 27 Dr. Roberts left Washington for Newcastle, Wyo., to inspect a site on the Cheyenne River where animal bones and artifacts were reported to be eroding from a gully bank and possible valuable information was in danger of being lost through the action of natural agencies. This investigation was just starting at the close of the fiscal year.

Dr. Julian H. Steward, anthropologist, continued his activities as editor of the Handbook of South American Indians. On September 2, 1941, Dr. A. Métraux was appointed to assist Dr. Steward in the preparation of the Handbook.

At the end of the fiscal year, completed manuscripts totaling about 600,000 words had been received from approximately 90 contributors. Half of the contributions are from Latin American scientists, while the remainder are from North American specialists on Middle and South American Indian tribes. The very important tribal map covering a large portion of South America was completed for the Handbook by Curt Nimuendaju and is now in Dr. Steward's hands. A collection of photographs of South American Indians was begun, and between 4,000 and 5,000 bibliographic items had been assembled.

From February to May 1942, Dr. Steward visited Brazil, Argentina, Paraguay, and Chile, where he conferred with Latin American anthropologists and arranged for their cooperation in matters pertaining to the Handbook. He also discussed plans for the formation of an "inter-American anthropological and geographic society," for

the development of cooperative anthropological and geographic research, and for the expansion of the exchange of publications. During this visit, Dr. Steward was made an honorary member of Academia Guaraní of Paraguay and Sociedad de Antropología de Argentina.

Dr. Steward has also served during the year as a member of the Policy Board of the American Indian Institute, the Advisory Board Strategic Index, and Publications Subcommittee of the Joint Committee on Latin American Studies.

During the past fiscal year, Dr. Henry B. Collins, Jr., ethnologist, continued with the study of archeological materials from prehistoric Eskimo village sites around Bering Strait. In April he presented a paper at the annual meeting of the American Philosophical Society, at Philadelphia, in which he discussed the relationships between prehistoric Eskimo culture and recently described Neolithic remains from the Lake Baikal region, southern Siberia, which have been regarded as the source of the basic American Indian culture. The paper, which is to be published in somewhat expanded form in the Proceedings of the Society, points out a number of close resemblances between the oldest Eskimo cultures—which probably date from around the beginning of the Christian era—and the Siberian Neolithic. The older stages of culture elsewhere in America, such as Folsom and Sandia, exhibit no such resemblances; it seems unlikely, therefore, that the Siberian Neolithic was the reservoir from which American culture in general was derived.

In the latter part of the fiscal year, Dr. Collins devoted considerable time to work in connection with the war effort, including the preparation of illustrated reports on various strategic areas. Preparation was also begun on a general paper on Alaska for the Smithsonian War Background Studies.

Dr. William N. Fenton, associate anthropologist, devoted the summer months of 1941 to the preparation of an introduction to his materials on Iroquois medical botany. Since a surprising number of Indian herbs have been taken into our pharmacopoeia, it was decided to publish the section on Contacts between Iroquois Herbalism and Colonial Medicine, a unit of itself, as an article in the appendix to the Annual Report of the Smithsonian Institution for 1941, reserving the balance of the study for a longer monograph.

In November, Dr. Fenton went to Brantford, Ontario, to work with Simeon Gibson of Six Nations Reserve at translating Onondaga texts bearing on the Iroquois League which his father, Chief John A. Gibson, had dictated to the late J. N. B. Hewitt. Of these the principal manuscript is a 189-page version in Onondaga of the "Deganawi'dah" legend of the founding of the Iroquois confederacy. Some 13 years later, Chief Gibson dictated a longer version of the same legend to Dr. Alex-

ander Goldenweiser, and this manuscript was turned over to Dr. Fenton some years ago by its collector. A translation of the Hewitt manuscript was completed in the field, and this has been reworked in part during the winter. Plans were made to translate the Goldenweiser manuscript during the ensuing year.

Two other research projects continued through the year. New materials were discovered by Dr. Fenton's collaborators in a study of Cornplanter's Senecas on the upper Allegheny River, mentioned in the report of last year, and the search for journals of the Quaker missions after 1798 has continued with some success. In this work Dr. Fenton acknowledges the labors of Messrs. M. H. Deardorff, of Warren, Pa., and C. E. Congdon, of Salamanca, N. Y., in transcribing manuscript sources and collecting much new material in the field.

The second project was conceived several years ago to fulfill a growing need among Americanists for an English edition of J. F. Lafitau's important but now rare Moeurs des Sauvages Ameriquains (2 vols., Paris, 1724). Dr. Elizabeth L. Moore, of Parkersburg, W. Va., onetime member of the French department at St. Lawrence University, has undertaken the translation, and at the end of the year had completed, under Dr. Fenton's direction, the translation of those sections in volume 1 which include Lafitau's observations of the American savages at his mission among the Mohawks of Caughnawaga and the Abenaki of nearby St. Francis, omitting for the most part long extracts from contemporary and earlier works that Lafitau felt obliged to copy. In order to conserve the Bureau's copy of this rare work, a microfilm copy was made, which is fortunate since the original library copy has been evacuated for the duration.

Early in March Dr. Fenton commenced compiling, with the help of Drs. Métraux, Collins, and Steward, a cumulative list of anthropologists arriving in Washington for war work and the agencies in which they were employed.

Following appointment to the Smithsonian War Committee on April 1, a large proportion of Dr. Fenton's time and efforts have gone into the work of the Committee, of which he has served as secretary. At his suggestion the Committee drafted and distributed questionnaires soliciting basic data for "A roster of personnel, world travel, and special knowledge available to war agencies at the Smithsonian Institution," and by early June the roster had been ushered through a preliminary and a first edition. The Smithsonian roster was patterned after personnel lists of the Oceania committee of the old "Ethnographic Board" of the National Research Council, and through these contacts the Smithsonian participated in setting up the Ethnogeographic Board. At the end of the fiscal year Dr. Fenton was detailed to act as an assistant to the director of the Board, Dr. William Duncan Strong.

During the year, Dr. Fenton delivered several illustrated lectures presenting some of the results of his studies of Iroquois culture.

At the end of the fiscal year a manuscript entitled "Songs from the Iroquois Longhouse; Program Notes for an Album of American Indian Music from the Eastern Woodlands" was accepted for publication by the Institution to accompany an album of phonograph records by the same title which the Archive of American Folk Song, Library of Congress, is bringing out as volume 6 of Folk Music of the United States.

Dr. Philip Drucker, assistant anthropologist, devoted the first half of the fiscal year to analysis of the pottery collections made in 1941 by the Smithsonian Institution-National Geographic Society expedition at Cerro de las Mesas, Veracruz, Mexico, and the preparation of a report on this material, Ceramic Stratigraphy at Cerro de las Mesas, Veracruz. Thanks to the cooperation of the Department of Archeology of the Mexican Government, he was able to study comparative collections of materials stored in the Museo Nacional de Mexico from adjacent regions, which greatly facilitated the placing of the Cerro de las Mesas culture. It was found that this site was occupied from a time level corresponding to that of Teotihuacán III of the Highland cultures until shortly before the Spanish conquest. The Ninth Cycle dates discovered in 1940 probably belong to the early period of occupation at Cerro de las Mesas. Of added interest is the fact that these dates are not only of importance to the archeology of the Gulf Coast, but in addition are the first actual carved dates even indirectly referable to the important center of civilization of the Mexican Highland, Teotihuacán. Following the period of Teotihuacán influence, a new set of influences appeared, probably an actual immigration, of Mixtecan people who brought with them their pottery craft, so that during the Upper Period at Cerro de las Mesas great quantities of Mixtecan-type (Cholultecan) wares were made. The modern designation of this coastal region as the "Mistequilla," incidentally, thus may be seen to be a well-based ethnic identification.

In the latter part of January, Dr. Drucker set out for the site of La Venta, in northwest Tabasco, where discoveries in 1940 indicated the importance of the place as an ancient ceremonial center. Excavations were carried out, aimed primarily at recovering stratigraphic material for the analysis and placing of the site in relation to the Tres Zapotes and Cerro de las Mesas "pottery yardsticks" established in former years, and for comparisons with material from more distant sites as well. Toward the end of the season some exploratory excavations were undertaken in structures at the site, especially in the large ceremonial patio. These efforts were rewarded by the finding of an elaborate tomb of basalt columns, and a number of pieces of small but exquisitely carved jade. Most of these jade pieces represent the little-known art

style often designated "Olmec," and are among the first of such objects to have been scientifically excavated. Their study will be important in defining and placing this art in its proper cultural context.

At the conclusion of the work, the materials were brought to Mexico City, where a division was made with the Department of Archeology of the Mexican Government. The entire body of stratigraphic materials, and a part of the remaining objects, were then shipped to Washington for purposes of study.

SPECIAL RESEARCHES

At the beginning of the fiscal year, Miss Frances Densmore, a collaborator of the Bureau, began the recording of Omaha songs at Macy, Nebr., on the Omaha Reservation. Musical studies had been made among the Omaha by Miss Alice C. Fletcher prior to 1893, and Miss Densmore wished, if possible, to contact singers who had recorded for Miss Fletcher and also to obtain duplicate recordings for comparative purposes. Among the older Indians, Miss Densmore located three singers, Edward Cline, Benjamin Parker, and Mattie Merrick White Parker, from whom songs had been obtained by Miss Fletcher. Miss Densmore recorded 32 songs from this group, including several which had been sung for Miss Fletcher. Joseph Hamilton and Henry J. Springer, who had been too young to sing for Miss Fletcher, were familiar with the songs of old war societies and recorded 33 songs. A third group comprised younger men, George R. Phillips, Robert Dale, and John G. Miller, from whom 6 songs connected with the first World War were obtained.

Some of Miss Fletcher's published Omaha songs were played on a piano and were recognized by the Indians as having been recorded for her. Miss Densmore obtained new recordings of these which were transcribed and compared with the versions presented by Miss Fletcher. It was noted that while the general effect of each melody is the same in both versions, differences are rather marked. An adequate comparison of the singing of these songs in the two periods of time could be made only if the original recordings were available for comparison with the records made in 1941. In contrast to the differences in these serious songs, it was said that the song of the hand game, presented by Miss Fletcher, is in use at the present time. This was re-recorded for the present work, and the two versions differ only in the omission in the new recording of a few bytones. From this it appears that songs in common use are preserved among the Omaha without change, while songs connected with ancient customs or ceremonies, which have not been sung for many years, are being forgotten and will soon disappear.

Miss Densmore also obtained from Benjamin Parker a description and a model of an old type of drum. In former times the cylinder

of this drum was a charred log, preferably of oak or elm. The lower head was of hide from the lower part of a buffalo's neck, and the upper head, which was struck, was made of deer hide or the hide from a hindquarter of an elk. These heads were laced together with buffalo thongs and tightened with bits of wood in the lacing, a custom not observed previously among the Indians.

During the year Miss Densmore arranged in final order 245 songs to accompany her manuscript on Seminole music and revised portions of the text to conform to this arrangement of the material.

In December 1941 Miss Densmore was appointed as consultant at The National Archives for work in connection with the Smithsonian-Densmore collection of sound recordings of American Indian music, and during the ensuing months she was engaged in planning the organization of the collection.

EDITORIAL WORK AND PUBLICATIONS

The editorial work of the Bureau has continued during the year under the immediate direction of the editor, M. Helen Palmer. There were issued one Annual Report and three Bulletins, as follows:

Fifty-eighth Annual Report of the Bureau of American Ethnology, 1940–1941. 13 pp.

Bulletin 129. An archeological survey of Pickwick Basin in the adjacent portions of the States of Alabama, Mississippi, and Tennessee, by William S. Webb and David L. DeJarnette. With additions by Walter B. Jones, J. P. E. Morrison, Marshall T. Newman and Charles E. Snow, and William G. Haag. 536 pp., 316 pls., 99 text figs.

Bulletin 130. Archeological investigations at Buena Vista Lake, Kern County, California, by Waldo R. Wedel. With appendix, Skeletal remains from the Buena Vista sites, California, by T. D. Stewart. 194 pp., 57 pls., 19 text figs.

Bulletin 131. Peachtree Mound and village site, Cherokee County, North Carolina, by Frank M. Setzler and Jesse D. Jennings. With appendix, Skeletal remains from the Peachtree Site, North Carolina, by T. D. Stewart. 103 pp., 50 pls., 12 text figs.

The following Bulletins were in press at the close of the fiscal year:

Bulletin 132. Source material on the history and ethnology of the Caddo Indians, by John R. Swanton.

Bulletin 133. Anthropological papers, numbers 19–26:

- No. 19. A search for songs among the Chitimacha Indians in Louisiana, by Frances Densmore.
- No. 20. Archeological survey on the northern Northwest Coast, by Philip Drucker.
- No. 21. Some notes on a few sites in Beaufort County, South Carolina, by Regina Flannery.
- No. 22. An analysis and interpretation of the ceramic remains from two sites near Beaufort, South Carolina, by James B. Griffin.

No. 23. The eastern Cherokees, by William Harlen Gilbert, Jr.

No. 24. Aconite poison whaling in Asia and America: An Aleutian transfer to the New World, by Robert F. Heizer.

No. 25. The Carrier Indians of the Bulkley River: Their social and religious life, by Diamond Jenness.

No. 26. The quipu and Peruvian civilization, by John R. Swanton.

Bulletin 134. Native tribes of eastern Bolivia and western Matto Grosso, by Alfred Métraux.

Bulletin 135. Origin myth of Acoma and other records, by Matthew W. Stirling.

Bulletin 136. Anthropological papers, numbers 27-32:

No. 27. Music of the Indians of British Columbia, by Frances Densmore.

No. 28. Choctaw music, by Frances Densmore.

No. 29. Some enthnological data concerning one hundred Yucatan plants, by Morris Steggerda.

No. 30. A description of 30 towns in Yucatan, 1937-39, with introductory and explanatory remarks, by Morris Steggerda.

No. 31. Some western Shoshoni myths, by Julian H. Steward.

No. 32. New material from Acoma, by Leslie A. White.

Bulletin 137. The Indians of the Southeastern United States, by John R. Swanton.

Publications distributed totaled 11,631.

LIBRARY

There has been no change in the library staff during the fiscal year. Accessions during the fiscal year totaled 350. Volumes received by exchange have fallen off sharply owing to the war, which has practically stopped exchange except from Great Britain and her possessions and from South America. Several new exchange sets have been started during the year.

The reclassification of the library is practically completed. The foreign society transactions and the foreign periodicals have been reshelved and a temporary shelflist made. The publications of Indian schools and missions have been classified, reshelved, and a temporary shelflist made. All available Library of Congress cards for periodicals in our collection have been obtained, and these cards have been sorted and will be prepared as soon as time permits.

The rare-book collection has been classified, reshelved, and shelflisted, and Library of Congress cards were obtained for nearly all this collection. About 600 volumes of the rare-book collection were packed for shipment to war storage in April.

New books received during the year have been classified and shelflisted and are now on the shelf. The usual work of recording new periodicals and society transactions and examining them for material of interest and for book reviews has been kept up to date.

A beginning has been made on bringing analytical entries up to date. The American Anthropologist, American Journal of Physical Anthropology, American Antiquity, and other important sets have been brought up to date with main cards only. Other sets and subject entries remain to be done.

The librarian attended the meetings of the Inter-American Bibliographical and Library Society in February 1942, and assisted in the formation of a Map and Geography group in the Washington chapter of the Special Libraries Association. Talks by the librarian on the library and the rare-book collection were given before the Map group of the Special Libraries Association on January 6, 1942, and before the Museum group on March 10, 1942.

ILLUSTRATIONS

During the year Mr. E. G. Cassedy, illustrator, continued the preparation of illustrations, maps, and drawings for the publications of the Bureau and for those of other branches of the Institution.

COLLECTIONS

Collections transferred by the Bureau of American Ethnology to the Department of Anthropology, United States National Museum, during the fiscal year were as follows:

Accession No.

161294. Cult objects from voodoo shrines in the region of Croix des Bouquets near Port-au-Prince, Haiti, and a small lot of archeological objects from Tortuga Island off the north coast of Haiti; collected by Dr. A. Métraux during the summer of 1941.

162205. Archeological materials from Ventura, Santa Barbara, Inyo, and Kern Counties, Calif., collected by Dr. W. D. Strong in 1934.

MISCELLANEOUS

During the course of the year information was furnished by members of the Bureau staff in reply to numerous inquiries concerning the North American Indians, both past and present, and the Mexican peoples of the prehistoric and early historic periods. Various specimens sent to the Bureau were identified and data on them furnished for their owners.

Personnel.—Dr. Philip Drucker was appointed on August 1, 1941, as assistant anthropologist; Dr. Alfred Métraux was appointed on September 2, 1941, as anthropologist; Miss Ethelwyn E. Carter was appointed on September 2, 1941, as assistant clerk-stenographer in connection with the preparation of the Handbook of South American Indians; Mrs. Catherine M. Phillips, junior stenographer, was pro-

moted to assistant clerk-stenographer on January 16, 1942, in the editorial division, Smithsonian Institution, and Mrs. Ruth S. Abramson was appointed on March 12, 1942, to fill this vacancy; W. B. Greenwood was transferred on February 12, 1942, to the United States National Museum, and on April 1, 1942, was reassigned to his former position in the Bureau library.

Respectfully submitted.

M. W. Stirling, *Chief.*

Dr. C. G. Abbot,
Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE INTERNATIONAL EXCHANGE SERVICE

SIR: I have the honor to submit the following report on the activities of the International Exchange Service for the fiscal year ended June 30, 1942:

The congressional appropriation for the Exchanges was $44,880, the same amount granted for the previous year. As was done last year, the Department of State transferred $500 to the Exchange Service from an appropriation made by Congress to that Department for carrying on its work of increasing the cultural relations between the United States and other American republics. This amount was used by the Exchange Service to send packages directly to correspondents in Argentina and Brazil by mail instead of forwarding them in boxes to exchange bureaus for distribution, thereby greatly reducing the time required for packages to reach their destinations. To all other South and Central American countries, as well as to Canada, Cuba, Dominican Republic, Haiti, Mexico, and Newfoundland, packages of publications are transmitted by mail under governmental frank. The $500 was not sufficient to meet the entire cost of postage on all the packages for Argentina and Brazil but the extra amount needed for this item was met from the congressional appropriation for the Exchanges. The total available resources for carrying on the exchange work was $48,505.50, there having been received during the year on account of repayments $3,125.50.

During the year 561,151 packages passed through the service, a decrease from last year of 15,131. The weight was 326,406 pounds, a decrease of 62,243 pounds. The publications sent and received through the Exchange Service are classified under three heads: Parliamentary documents, departmental documents, and miscellaneous scientific and literary publications. The term "parliamentary documents," as here used, refers to publications set aside by act of Congress for exchange with foreign governments, and includes not only documents printed by order of either House of Congress, but also copies of each publication issued by any department, bureau, commission, or officer of the Government. Governments to which this class of publications are forwarded send to this country in exchange copies of their own official documents for deposit in the Library of Congress. The term "departmental documents" embraces publica-

tions delivered at the Institution by governmental departments, bureaus, or commissions for distribution to their correspondents abroad. Publications received in return are deposited in the various departmental libraries. "Miscellaneous scientific and literary publications" are received chiefly from learned societies, universities, colleges, scientific institutions, and museums in the United States for transmission to similar establishments in all parts of the world.

Detailed figures under these three headings are given in the following table:

	Packages		Weight	
	Sent abroad	Received from abroad	Sent abroad	Received from abroad
			Pounds	*Pounds*
United States parliamentary documents sent abroad	365,620		125,798	
Publications received in return for parliamentary documents		201		1,555
United States departmental documents sent abroad	93,247		87,432	
Publications received in return for departmental documents		1,033		2,508
Miscellaneous scientific and literary publications sent abroad	93,377		94,655	
Miscellaneous scientific and literary publications received from abroad for distribution in the United States		7,673		14,458
Total	552,244	8,907	307,885	18,521
Grand total	561,151		326,406	

Packages are forwarded abroad partly by freight to exchange bureaus for distribution and partly by mail directly to their destinations. The number of boxes shipped was 599, a decrease from last year of 366. Of these boxes 304 were for depositories of full sets of governmental documents and the contents of the remainder (295) were for depositories of partial sets and for various establishments and individuals. The number of mail packages was 127,454.

The work of the Service is still greatly interfered with by the war, which at the close of the year had resulted in the suspension of shipments of exchanges to all countries in the Eastern Hemisphere except Great Britain and the Union of South Africa. In the Western Hemisphere, where packages are forwarded to their destinations by mail, mostly under governmental frank, there has been no interruption to the sending of packages, although some delay results from their examination by the Office of Censorship before being allowed to leave the United States.

The dates of the last shipments to the countries to which the sending of consignments was suspended during the year are given below:

India	Oct. 17, 1941
Portugal	Apr. 7, 1942
Sweden	Dec. 2, 1941
Switzerland	Dec. 8, 1941
New Zealand	Sept. 22, 1941

New South Wales	Dec. 22, 1941
Queensland	Do.
South Australia	Do.
Tasmania	Sept. 22, 1941
Victoria	Dec. 22, 1941
Western Australia	Sept. 22, 1941

FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

There now are received at the Institution for transmission through the International Exchange Service to foreign depositories 55 full sets and 36 partial sets of United States governmental documents—a total of 91 sets. At the close of the year no sets of governmental documents were being forwarded to any countries in the Eastern Hemisphere. In the Western Hemisphere the full and partial series were being transmitted after eliminating those publications not allowed to be exported by the Office of Censorship because they were considered to contain matter of possible aid to the enemy. All the publications forming the full and partial sets of governmental documents now being held will be forwarded at the close of the war.

The depository in South Australia was changed from the Parliamentary Library to the Public Library. The partial sets sent to the Straits Settlements and the State of Rio de Janeiro were discontinued. The Biblioteca Nacional in San Salvador was added to the list of depositories of those sets.

A complete list of the depositories is given below:

DEPOSITORIES OF FULL SETS

ARGENTINA: Dirección de Investigaciones, Archivo, Biblioteca y Legislación Extranjera, Ministerio de Relaciones Exteriores y Culto, Buenos Aires.

AUSTRALIA: Commonwealth Parliament and National Library, Canberra.
- NEW SOUTH WALES: Public Library of New South Wales, Sydney.
- QUEENSLAND: Parliamentary Library, Brisbane.
- SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.
- TASMANIA: Parliamentary Library, Hobart.
- VICTORIA: Public Library of Victoria, Melbourne.
- WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

BELGIUM: Bibliothèque Royale, Bruxelles.

BRAZIL: Instituto Nacional do Livro, Rio de Janeiro.

CANADA: Library of Parliament, Ottawa.
- MANITOBA: Provincial Library, Winnipeg.
- ONTARIO: Legislative Library, Toronto.
- QUEBEC: Library of the Legislature of the Province of Quebec.

CHILE: Biblioteca Nacional, Santiago.

CHINA: Bureau of International Exchange, Ministry of Education, Chungking.

COLOMBIA: Biblioteca Nacional, Bogotá.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CUBA: Ministerio de Estado, Dirección de Relaciones Culturales, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.

DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.
EGYPT: Bureau des Publications, Ministère des Finances, Cairo.
ESTONIA: Riigiraamatukogu (State Library), Tallinn.
FINLAND: Parliamentary Library, Helsinki.
FRANCE: Bibliothèque Nationale, Paris.
GERMANY: Reichstauschstelle im Reichsministerium für Wissenschaft, Erziehung und Volksbildung, Berlin, N. W. 7.
PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.
GREAT BRITAIN:
ENGLAND: British Museum, London.
LONDON: London School of Economics and Political Science. (Depository of the London County Council.)
HUNGARY: Library, Hungarian House of Delegates, Budapest.
INDIA: Imperial Library, Calcutta.
IRELAND: National Library of Ireland, Dublin.
ITALY: Ministero dell'Educazione Nazionale, Rome.
JAPAN: Imperial Library of Japan, Tokyo.
LATVIA: Bibliothèque d'État, Riga.
LEAGUE OF NATIONS: Library of the League of Nations, Geneva, Switzerland.
MEXICO: Dirección General de Información, Secretaría de Gobernación, Mexico, D. F.
NETHERLANDS: Royal Library, The Hague.
NEW ZEALAND: General Assembly Library, Wellington.
NORTHERN IRELAND: H. M. Stationery Office, Belfast.
NORWAY: Universitets-Bibliothek, Oslo. (Depository of the Government of Norway.)
PERU: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.
POLAND: Bibliothèque Nationale, Warsaw.
PORTUGAL: Biblioteca Nacional, Lisbon.
RUMANIA: Academia Română, Bucharest.
SPAIN: Cambio Internacional de Publicaciones, Avenida de Calvo Sotelo 20, Madrid.
SWEDEN: Kungliga Biblioteket, Stockholm.
SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.
TURKEY: Department of Printing and Engraving, Ministry of Education, Istanbul.
UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.
UNION OF SOVIET SOCIALIST REPUBLICS: All-Union Lenin Library, Moscow 115.
UKRAINE: Ukrainian Society for Cultural Relations with Foreign Countries, Kiev.
URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.
VENEZUELA: Biblioteca Nacional, Caracas.
YUGOSLAVIA: Ministère de l-Éducation, Belgrade.

DEPOSITORIES OF PARTIAL SETS

AFGHANISTAN: Ministery of Foreign Affairs, Publications Department, Kabul.
BOLIVIA: Biblioteca del Ministerio de Relaciones Exteriores y Culto, La Paz.
BRAZIL:
MINAS GERAES: Directoria Geral de Estatistica em Minas, Bello Horizonte.
BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.
CANADA:
ALBERTA: Provincial Library, Edmonton.
BRITISH COLUMBIA: Provincial Library, Victoria.

CANADA—Continued.

NEW BRUNSWICK: Legislative Library, Fredericton.

NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.

PRINCE EDWARD ISLAND: Legislative and Public Library, Charlottetown.

SASKATCHEWAN: Legislative Library, Regina.

CEYLON: Chief Secretary's Office (Record Department of the Library), Colombo.

CHINA: National Library of Peiping.

DOMINICAN REPUBLIC: Biblioteca del Senado, Ciudad Trujillo.

ECUADOR: Biblioteca Nacional, Quito.

GUATEMALA: Biblioteca Nacional, Guatemala.

HAITI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS:

Biblioteca y Archivo Nacionales, Tegucigalpa.

Ministerio de Relaciones Exteriores, Tegucigalpa.

ICELAND: National Library, Reykjavik.

INDIA:

BENGAL: Secretary, Bengal Legislative Council Department, Council House, Calcutta.

BIHAR AND ORISSA: Revenue Department, Patna.

BOMBAY: Undersecretary to the Government of Bombay, General Department, Bombay.

BURMA: Secretary to the Government of Burma, Education Department, Rangoon.

PUNJAB: Chief Secretary to the Government of the Punjab, Lahore.

UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.

JAMAICA: Colonial Secretary, Kingston.

LIBERIA: Department of State, Monrovia.

MALTA: Minister for the Treasury, Valletta.

NEWFOUNDLAND: Department of Home Affairs, St. John's.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

PANAMA: Ministerio de Relaciones Exteriores, Panama.

PARAGUAY: Secretario de la Presidencia de la República, Asunción.

SALVADOR:

Biblioteca Nacional, San Salvador.

Ministerio de Relaciones Exteriores, San Salvador.

THAILAND: Department of Foreign Affairs, Bangkok.

VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City, Italy.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

The number of depositories of the Congressional Record and Federal Register was reduced during the first 9 months of the year, the number forwarded being 71. Those sent to the following countries were discontinued in March 1942: Gibraltar, Hungary, Indochina, Netherlands Indies, Rumania (2 copies), and Vatican City. In April 1942, the sending of the Congressional Record to foreign countries through the International Exchange Service was discontinued for the duration of the war by request of the Office of Censorship.

DEPOSITORIES OF CONGRESSIONAL RECORD

ARGENTINA:
- Biblioteca del Congreso Nacional, Buenos Aires.
- Cámara de Diputados, Oficina de Información Parlamentaria, Buenos Aires.
- Boletín Oficial de la República Argentina, Ministerio de Justicia e Instrucción Pública, Buenos Aires.

AUSTRALIA:
- Commonwealth Parliament and National Library, Canberra.
- NEW SOUTH WALES: Library of Parliament of New South Wales, Sydney.
- QUEENSLAND: Chief Secretary's Office, Brisbane.
- WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.

BRAZIL:
- Biblioteca do Congresso Nacional, Rio de Janeiro.
- AMAZONAS: Archivo, Biblioteca e Imprensa Publica, Manãos.
- BAHIA: Governador do Estado da Bahia, São Salvador.
- ESPIRITO SANTO: Presidencia do Estado do Espirito Santo, Victoria.
- RIO GRANDE DO SUL: "A Federação," Porto Alegre.
- SERGIPE: Biblioteca Publica do Estado de Sergipe, Aracajú.
- SÃO PAULO: Diario Official do Estado de São Paulo, São Paulo.

BRITISH HONDURAS: Colonial Secretary, Belize.

CANADA:
- Library of Parliament, Ottawa.
- Clerk of the Senate, Houses of Parliament, Ottawa.

CUBA: Biblioteca del Capitolio, Habana.

EGYPT:
- Chambre des Députés, Cairo.
- Sénat, Cairo.

GREAT BRITAIN: Library of the Foreign Office, London.

GUATEMALA: Biblioteca de la Asamblea Legislativa, Guatemala.

HAITI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.

INDIA: Legislative Department, Simla.

IRAN: Library of the Iranian Parliament, Téhéran.

IRAQ: Chamber of Deputies, Baghdad.

IRISH FREE STATE: Dail Eireann, Dublin.

LEAGUE OF NATIONS: Library of the League of Nations, Geneva, Switzerland.

LEBANON: Ministère des Finances de la République Libanaise, Service du Matériel, Beirut.

LIBERIA: Department of State, Monrovia.

MEXICO: Dirección General de Información, Secretaría de Gobernación, Mexico, D. F.
- AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.
- CAMPECHE: Gobernador del Estado de Campeche, Campeche.
- CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Gutierrez.
- CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.
- COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.
- COLIMA: Gobernador del Estado de Colima, Colima.
- DURANGO: Gobernador Constitucional del Estado de Durango, Durango.
- GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.
- GUERRERO: Gobernador del Estado de Guerrero, Chilpancingo.
- JALISCO: Biblioteca del Estado, Guadalajara.

MEXICO—Continued.

LOWER CALIFORNIA: Gobernador del Distrito Norte, Mexicali.

MÉXICO: Gaceta del Gobierno, Toluca.

MICHOACÁN: Secretaría General de Gobierno del Estado de Michoacán, Morelia.

MORELOS: Palacio de Gobierno, Cuernavaca.

NAYARIT: Gobernador de Nayarit, Tepic.

NUEVO LEÓN: Biblioteca del Estado, Monterrey.

OAXACA: Periódico Oficial, Palacio de Gobierno, Oaxaca.

PUEBLA: Secretaría General de Gobierno, Puebla.

QUERÉTARO: Secretaría General de Gobierno, Sección de Archivo, Querétaro.

SAN LUIS POTOSÍ: Congreso del Estado, San Luis Potosí.

SINALOA: Gobernador del Estado de Sinaloa, Culiacán.

SONORA: Gobernador del Estado de Sonora, Hermosillo.

TABASCO: Secretaría General de Gobierno, Sección 3a, Ramo de Prensa, Villahermosa.

TAMAULIPAS: Secretaría General de Gobierno, Victoria.

TLAXCALA: Secretaría de Gobierno del Estado, Tlaxcala.

VERACRUZ: Gobernador del Estado de Veracruz, Departamento de Gobernación y Justicia, Jalapa.

YUCATÁN: Gobernador del Estado de Yucatán, Mérida, Yucatán.

NEW ZEALAND: General Assembly Library, Wellington.

PERU: Cámara de Diputados, Lima.

SWITZERLAND: Bibliothèque de l'Assemblée Fédérale Suisse, Berne.

BERN: Staatskanzlei des Kantons Bern.

ST. GALLEN: Staatskanzlei des Kantons St. Gallen.

SCHAFFHAUSEN: Staatskanzlei des Kantons Schaffhausen.

ZÜRICH: Staatskanzlei des Kantons Zürich.

TURKEY: Turkish Grand National Assembly, Ankara.

UNION OF SOUTH AFRICA:

Library of Parliament, Cape Town, Cape of Good Hope.

State Library, Pretoria, Transvaal.

URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.

VENEZUELA: Biblioteca del Congreso, Caracas.

FOREIGN EXCHANGE AGENCIES

The following is a list of bureaus or agencies to which consignments are forwarded in boxes by freight when the Service is in full operation To all countries not appearing in the list, packages are sent directly to their destinations by mail.

LIST OF AGENCIES

ALGERIA, via France.

ANGOLA, via Portugal.

AUSTRIA, via Germany.

AZORES, via Portugal.

BELGIUM: Service Belge des Échanges Internationaux, Bibliothèque Royale de Belgique, Bruxelles.

CANARY ISLANDS, via Spain.

CHINA: Bureau of International Exchange, Ministry of Education, Chungking.

CZECHOSLOVAKIA: Service des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1-79.

DENMARK: Service Danois des Échanges Internationaux, Kongelige Danske Videnskabernes Selskab, Copenhagen V.

EGYPT: Government Press, Publications Office, Bulaq, Cairo.

FINLAND: Delegation of the Scientific Societies of Finland, Kasärngatan 24, Helsinki.

FRANCE: Service Français des Échanges Internationaux, 110 Rue de Grenelle, Paris.

GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.

GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 721 North Circular Road, Willesden, London, NW. 2.

HUNGARY: Hungarian Libraries Board, Ferenciektere 5, Budapest, IV.

INDIA: Superintendent of Government Printing and Stationery, Bombay.

ITALY: Ufficio degli Scambi Internazionali, Ministero dell'Educazione Nazionale, Rome.

JAPAN: International Exchange Service, Imperial Library of Japan, Uyeno Park, Tokyo.

LATVIA: Service des Échanges Internationaux, Bibliothèque d'État de Lettonie, Riga.

LUXEMBOURG, via Belgium.

MADAGASCAR, via France.

MADEIRA, via Portugal.

MOZAMBIQUE, via Portugal.

NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.

PALESTINE: Jewish National and University Library, Jerusalem.

POLAND: Service Polonais des Échanges Internationaux, Bibliothèque Nationale, Warsaw.

PORTUGAL: Secção de Trocas Internacionaes, Biblioteca Nacional, Lisbon.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

RUMANIA: Ministère de la Propagande Nationale, Service des Échanges Internationaux, Bucharest.

SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.

SPAIN: Junta de Intercambio y Adquisición de Libros y Revistas para Bibliotecas Públicas, Ministerio de Educación Nacional, Avenida Calvo Sotelo, 20, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Berne.

TASMANIA: Secretary to the Premier, Hobart.

TURKEY: Ministry of Education, Department of Printing and Engraving, Istanbul.

UNION OF SOUTH AFRICA: Government Printing and Stationery Office, Cape Town, Cape of Good Hope.

UNION OF SOVIET SOCIALIST REPUBLICS: International Book Exchange Department, Society for Cultural Relations with Foreign Countries, Moscow, 56.

VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
YUGOSLAVIA: Section des Échanges Internationaux, Ministère des Affaires Étrangères, Belgrade.

C. W. Shoemaker, Chief Clerk of the Exchanges, was retired on November 30, 1941, after more than 59 years of service with the Institution and after having worked 11 years over the statutory retirement age of 70. In this connection it may be mentioned that the International Exchanges is noted for the length of service of some of its employees. M. A. Tolson has served under the Institution for more than 61 years and F. E. Gass for 55 years.

Respectfully submitted.

F. E. GASS, *Acting Chief Clerk.*

Dr. C. G. ABBOT,
Secretary, Smithsonian Institution.

APPENDIX 7

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ended June 30, 1942:

The regular appropriation made by Congress was $239,260, all of which was expended with the exception of $4,000, which represents savings of salaries for positions not filled.

PERSONNEL

In common with other agencies, the Zoo has had considerable personnel turn-over, losing a number of its capable employees through transfer to military service. These have been replaced, as far as possible, with employees who will serve for the duration and until the return of the regular staff.

IMPROVEMENTS

The cessation of W. P. A. work and the conditions resulting from the war have prevented the making of material improvements. Before our entry into the war, a small amount of work was done at the reptile pit in front of the reptile house to improve its appearance as a natural habitat area.

NEEDS OF THE ZOO

The needs of the Zoo remain the same as outlined in previous reports. On account of war conditions, no request is being made for unusual expenditures at this time.

VISITORS FOR THE YEAR

The attendance for the year was slightly more than that for last year. The tire and gasoline rationing which went into effect in late spring brought about a perceptible increase in visitors by bus and streetcar and on foot.

July	241,300	February	101,500
August	278,400	March	159,900
September	235,300	April	244,500
October	251,800	May	217,200
November	203,200	June	248,100
December	161,000		
January	121,100	Total	2,523,300

The attendance of organizations, mainly classes of students, of which there is definite record, was 10,660, from 212 different schools or groups in 15 States and the District of Columbia. This large decrease from last year of visitors in this group was due mainly to restrictions on chartered bus travel which went into effect the first part of June, a month during which the largest number of schools or classes usually visit the Zoo. A complete listing by States follows:

State	Number of persons	Number of parties	State	Number of persons	Number of parties
Connecticut	179	4	North Carolina	281	8
Delaware	48	2	Ohio	28	1
District of Columbia	1,638	35	Pennsylvania	2,509	45
Maine	42	1	South Carolina	244	9
Maryland	1,375	21	Tennessee	35	1
Massachusetts	439	8	Virginia	1,232	33
Michigan	176	2	West Virginia	220	6
New Jersey	1,023	20			
New York	530	6	Total	10,660	212

As in preceding years, a census was made every afternoon at about 3 o'clock of the cars parked on the Zoo ground. During the year 56,585 cars were so listed, representing every State in the Union, as well as Alaska, Brazil, Canal Zone, Cuba, Guatemala, Haiti, Hawaii, Mexico, Puerto Rico, Panama, Philippine Islands, and Venezuela.

This count is not of value as showing a total attendance, but only as indicating the percentage of attendance by States. The record for the year shows that the District of Columbia automobiles comprised 39 percent, Maryland 22 percent, Virginia 15 percent, Pennsylvania 4 percent; and the remaining 20 percent were from other States, Territories, and countries.

The attendance at the Zoo reflects changed conditions incident to the war. Formerly there were relatively few visitors in the early days of the week and in the mornings, but now there is a pronounced increase during these periods, so that the highs and lows of attendance are less pronounced.

Owing to the large increase in Washington population, the local attendance at the Zoo has so increased that it offsets the decrease in the number of transient visitors brought about by the curtailment of automobile travel.

Large numbers of men in uniform are enjoying their first opportunity to visit a large zoo, and some groups of injured or sick are brought by nurses or Red Cross drivers. The Zoo continues to be a regular study ground for art and biology classes, as well as an important focal point for letters, telephone calls, and personal queries regarding animals, their behavior, and methods to be followed in preventing or remedying injuries from animals, how to care for animals, and many miscellaneous questions.

AIR-RAID PRECAUTIONS

So far as can be learned, the experience of other zoos in the war area suggests that the National Zoological Park will probably be one of the safest places about Washington during air raids. By the very nature of the construction of most of the cages, it is practically certain that any dangerous animal would be killed if it were in a cage damaged badly enough to let the animal escape.

The Zoo has endeavored to take precautions to provide for such contingencies as may arise. A number of key men have received instruction regarding incendiary bombs, gas bombs, and first aid, and the entire organization has been instructed and drilled in taking their respective posts during daylight tests and raids. The personnel has been divided into groups, so that in the event of attacks becoming imminent, the practice will be inaugurated of requiring some of the personnel to remain in the Zoo overnight, in order to be available in the event of emergency. This is with the idea of having trained men for emergencies at night, as well as during daytime.

ACCESSIONS

FIELD WORK

On account of world conditions, no expeditions were sent abroad; hence the Zoo did not receive the large numbers of animals that are usually brought in by such efforts.

GIFTS

Among important gifts during the year was a magnificent Texas longhorn steer from the ranch of Col. T. T. East, brought to Washington through the courtesy of the Texas and Southwestern Cattle Raisers Association. The animal was presented to the Zoo by the Texas State Society through the Honorable Wright Patman, and, as the first of its kind ever to be shown in the collection, it has attracted a great deal of attention.

A pet mule deer fawn was received from L. S. Marriott, Soda Springs, Idaho. Dr. Carlos G. Aguayo, of Habana, Cuba, presented a very rare Cuban crocodile (*Crocodylus rhombifer*), the first ever exhibited here. Otto Martin Locke, of New Braunfels, Tex., presented a large number of horned lizards and a nine-banded armadillo. From Kenly Chiles, of Washington, D. C., was received a guenon monkey.

Dr. Thomas Barbour, Director of the Museum of Comparative Zoology at Cambridge, Mass., presented two extra large and fine specimens of the African lungfish, which he had kept for observation since 1937.

DONORS AND THEIR GIFTS

Dr. Carlos G. Aguayo, Habana, Cuba, Cuban crocodile.
G. B. Arthur, Washington, D. C., common rabbit.
Clarence Attwood, Rockville, Md., duck hawk.
Baltimore & Ohio Freight Office, Washington, D. C., skunk.
Dr. T. Barbour, Cambridge, Mass., 2 African lungfish.
Carl Beale, Washington, D. C., gray fox.
Edgar Beckley, Washington, D. C., night hawk.
Mr. and Mrs. B. A. Bower, Mount Rainier, Md., 7 canaries.
D. Bresnahan, Washington, D. C., alligator.
R. A. Brown, Chevy Chase, Md., screech owl.
J. A. Bryant, Waverly, Va., otter.
Ruth Buchanan, Washington, D. C., grass parequet.
Mrs. Frank R. Chase, Takoma Park, Md., Pekin duck.
Kenly Chiles, Washington, D. C., green guenon.
J. A. Clark, Silver Spring, Md., golden pheasant.
Marvin Cohen and Bill Wright, Washington, D. C., alligator.
Ralph E. Day, Washington, D. C., horned lizard.
Mrs. L. Diggs, Berwyn, Md., sparrow hawk.
Barney Dillard, Emporia, Fla., box tortoise.
Charles F. Dodge, Washington, D. C., sharp-shinned hawk.
William H. Dorsey, Arlington, Va., alligator.
Col. T. T. East, Hebbronville, Tex., Texas longhorn steer.
Col. H. E. Eastwood, Washington, D. C., common rabbit.
Hon. Clyde T. Ellis, Washington, D. C., opossum.
Alden Evans and George Clarke, Washington, D. C., copperhead.
Mrs. James L. Ewin, Washington, D. C., alligator.
Robert J. Feeney, Washington, D. C., ferret.
Dr. J. H. Ferguson, Washington, D. C., bald eagle.
Fish and Wildlife Service, Pawtuxent Research Refuge: through Ford Wilkie, 2 barn owls; through F. C. Lincoln, Washington, D. C., hybrid duck; through F. T. Staunton, Moffit, N. Dak., 4 Hutchins geese, 1 white-fronted goose; through William C. Bunch, Edenton, N. C., great blue heron; through John N. Hamlet, Washington, D. C., 16 cotton rats, 2 southern pocket gophers, 7 round-tailed wood rats, 5 ord kangaroo rats, 4 collared lizards, 3 coachwhip snakes, 2 striped racerunners, whip-tailed lizard, 13 Holbrook's lizards.
Mrs. E. H. Fisher, Washington, D. C., zebra finch.
James B. Fox, Washington, D. C., goshawk.
Paul Fundenberg, Fort Lauderdale, Fla., marine turtle.
Kathleen Garvin, Chevy Chase, Md., box tortoise.
Mrs. J. F. Gates, Hyattsville, Md., 4 eastern weasels.
L. J. Gauthier, Washington, D. C., Pekin duck.
Mrs. Malcolm George, Silver Spring, Md., yellow-naped parrot.
Jane Gibbons, Washington, D. C., horned lizard.
A. F. Gibson, Washington, D. C., woodchuck or ground hog.
Richard Goetz, Waldorf, Md., 2 red-tailed hawks.
J. S. Goldsmith, Washington, D. C., 6 box tortoises, 2 painted turtles, pilot snake.

W. Bart Greenwood, Smithsonian Institution, Washington, D. C., 2 southern red-shouldered hawks, western diamond-back rattlesnake.
Mr. Greeson, Washington, D. C., 2 banded rattlesnakes.
Mrs. F. S. Haas, Kenwood, Md., goose.
Winifree Hall, Washington, D. C., night hawk.
E. W. Harkins, Washington, D. C., ring-necked pheasant.
M. Heiberg, Arlington, Va., opossum.
L. A. Helms, Takoma Park, Md., rhesus monkey.
Henlopin Game Farms, Milton, Del., 2 ring-necked pheasants.
A. S. Henning, Washington, D. C., flying squirrel.
R. W. Henrich and B. F. Parris, Washington, D. C., red fox.
Fred Hill, Washington, D. C., skunk.
Russell Hill, Washington, D. C., great horned owl.
Ella Holmes, Washington, D. C., common rabbit.
D. F. Humphrey, Washington, D. C., blacksnake, 2 chicken snakes, 2 water snakes, garter snake.
R. F. Johnson, Washington, D. C., rhesus monkey.
Mrs. L. Jones, Washington, D. C., red, blue, and yellow macaw.
Mrs. W. A. Justice, Edgewater, Md., double yellow-head parrot.
Mrs. J. E. Keel, Washington, D. C., common marmoset.
Gail and Lynn Kerwin, Washington, D. C., 2 white rabbits.
M. King, Takoma Park, Md., opossum.
W. M. King, Washington, D. C., snapping turtle.
Mrs. B. Krasnick, Chevy Chase, Md., common boa, water snake, 2 fence lizards, 2 brown skinks, 5 glass snakes or legless lizards, 11 toads.
E. D. Lambert, Washington, D. C., woodchuck or ground hog.
Otto M. Locke, New Braunfels, Tex., 100 horned lizards, 9-banded armadillo.
A. Loveridge, Cambridge, Mass., 7 turtles.
Col. T. H. Lowe, Washington, D. C., barred owl.
Walter Lucas, Washington, D. C., gray fox.
W. Mansfield, Washington, D. C., common rabbit.
L. S. Marriott, Soda Springs, Idaho, mule deer.
R. S. Mathew, New York Aquarium, New York, N. Y., boa constrictor.
Mrs. E. Matteossian, Bethesda, Md., 4 flying squirrels.
Mr. May, Washington, D. C., chain or king snake.
Adam S. McAllister and Micah H. Naftalin, Washington, D. C., brown bat.
H. H. McClure, Washington, D. C., 2 false chameleons, box tortoise.
M. McClure, Washington, D. C., alligator.
Mrs. J. C. Meisle, Washington, D. C., 4 grass paroquets.
F. C. Metcalfe, Washington, D. C., white-throated capuchin.
Metropolitan Police, Precinct No. 12, Washington, D. C., muscovy duck.
R. Miller, Washington, D. C., 3 opossums.
W. S. Morlan, Washington, D. C., hog-nosed snake.
M. Moser, Washington, D. C., barred owl.
Mrs. J. Murphy, Washington, D. C., 2 grass paroquets.
Martha Nuland, Washington, D. C., alligator.
A. Parsell, Buena Vista, Va., banded rattlesnake.
Mrs. Peterson, Washington, D. C., small finch.
A. S. Polito, Washington, D. C., barn owl.
J. J. Porter, Davis, Okla., bald eagle.

L. Poston, Washington, D. C., soft-shelled turtle.
Mr. and Mrs. W. J. Preston, Baltimore, Md., 2 bishop weavers.
Bunny Reid, Washington, D. C., Pekin duck.
Nancy Reynolds, Washington, D. C., 2 Pekin ducks.
Mrs. R. H. Rhodes, Washington, D. C., opossum.
H. M. Rice, Germantown, Md., painted turtle.
J. L. Richardson, Richmond, Va., rhesus monkey.
Bertrand Robbins, Washington, D. C., chain or king snake.
Louis Ruhe, Inc., New York, N. Y., 2 collared finch-billed bulbuls.
Samuel Russell, Washington, D. C., 23 horned lizards.
Mrs. W. Rutledge, Washington, D. C., 2 Pekin ducks.
San Diego Zoo, San Diego, Calif., kinkajou, 3 ring-tail or cacomistle.
Walter Schmidt, Bethesda, Md., alligator.
Mrs. W. L. Schubert, Washington, D. C., common rabbit.
D. S. Scott, Washington, D. C., copperhead.
Col. Shaleriadd, Chevy Chase, Md., alligator.
Mrs. Joseph Smith, Washington, D. C., grass paroquet.
Daisy Rice Spradling, Athens, Tenn., banded rattlesnake.
Corp. W. D. Sprouse, Vienna, Va., red fox.
James Stallings, Washington, D. C., alligator.
Mrs. S. Stanley, Greenacres, Md., Pekin duck.
Mr. Stone, Wardman Park Hotel, Washington, D. C., duck hawk.
W. W. Swaggart, Washington, D. C., canary.
Mrs. George Swanson, Mount Rainier, Md., 2 Pekin ducks, 3 Toulouse geese.
Bertha Sweet, Washington, D. C., 2 common rabbits.
Mrs. Thomas Terry, Witchville, Md., yellow-head parrot.
D. C. Thomas, Washington, D. C., black snake.
Ira B. Tice, Washington, D. C., Pekin ducks.
L. W. Turner, Washington, D. C., Pekin ducks.
T. Van Hyning, Gainesville, Fla., bald eagle.
Senator Frederick Van Nuys, Vienna, Va., rhesus monkey.
Mrs. Van Patten, Washington, D. C., Pekin duck.
A. W. Walker, Takoma Park, Md., opossum.
Ernest P. Walker, National Zoological Park, Washington, D. C., 2 picket pin ground squirrels, golden-breasted mouse, 3 True's white-footed mice, 2 grasshopper mice, Hopi chipmunk, golden-mantled ground squirrel, 2 5-toed kangaroo rats, 5 Uinta ground squirrels, 6 13-striped ground squirrels, 2 northern chipmunks, 10 plains toads, least weasel or ermine.
Miss V. Walston, Takoma Park, Md., red fox.
W. F. Ward, Washington, D. C., raccoon.
Mrs. J. M. Waters, Bethesda, Md., cottontail rabbit.
J. C. Watters, Atlanta, Ga., 2 raccoons.
J. M. Weedon, Washington, D. C., muscovy duck.
Fletcher Welch, Washington, D. C., Pekin duck.
F. C. Wells, Washington, D. C., barred owl.
Mrs. H. E. White, Washington, D. C., 2 box tortoises.
Mrs. H. A. Wood, Washington, D. C., Mexican parrot.
Walter Wuenschel, Washington, D. C., painted turtle.
Carlo Zeimet, Vienna, Va., peafowl.

BIRTHS

There were 65 mammals born, 40 birds hatched, and 2 reptiles born during the year.

MAMMALS

Scientific name	Common name	Number
Ammotragus lervia	Aoudad	4
Axis axis	Axis deer	3
Bibos gaurus	Gaur	1
Bison bison	American bison	3
Bos indicus	Zebu	1
Camelus bactrianus	Bactrian camel	1
Cephalophus nigrifrons	Black-fronted duiker	1
Cervus canadensis	Elk	1
Cervus elaphus	European red deer	2
Choloepus didactylus	Two-toed sloth	1
Cynomys ludovicianus	Prairie dog	12
Dama dama	Fallow deer	6
Dolichotis magellanica	Patagonian cavy	2
Felis onca	Jaguar	3
Hippopotamus amphibius	Hippopotamus	1
Lama glama	Llama	1
Macaca mulatta	Rhesus monkey	1
Macaca nemestrina	Pig-tailed macaque	2
Magus maurus	Moor monkey	1
Myocastor coypu	Nutria or coypu	6
Poephagus grunniens	Yak	1
Potos flavus	Kinkajou	1
Pseudois nahura	Bharal or blue sheep	2
Sciurus finlaysoni	Lesser white squirrel	2
Sika nippon	Japanese deer	1
Synceros caffer	African buffalo	1
Tapirus terrestris	South American tapir	1
Vulpes fulva	Red fox	1

BIRDS

Anas platyrhynchos	Mallard	12
Calopezus elegans	Crested tinamou	2
Limnocorax flavirostra	African black rail	10
Nycticorax nycticorax naevius	Black-crowned night heron	16

REPTILES

Zonurus giganteus	Spiny lizard	2

EXCHANGES

A splendid pair of British Park cattle was received in exchange from the Zoo at Toronto, Canada; and from W. A. King, at Brownsville, Tex., were received 6 Yucatan jays, 4 Mexican caciques, a pair of spider monkeys, 4 red-bellied squirrels, and a pair of West Highland or Kyloe cattle.

PURCHASES

Important specimens acquired by purchase were a secretary bird; a number of South African snakes, which were obtained from the Fitzsimons' Snake Farm, Durban, South Africa; 6 two-toed sloths; a pair of raccoon dogs; and a pair of East African wart hogs. Also purchased during the year were a pair of guanacos and a pair of single-humped camels. This provides specimens of all living forms of the camel family.

REMOVALS

Many of the poisonous reptiles have been removed from the Zoo, leaving so few in the collection that they can be instantly disposed of should the occasion require.

In the report for 1941, there was described a very serious loss of birds resulting from an epidemic of psittacosis in the bird house. The bird house was closed to the public for about 3 months, and at the beginning of this fiscal year the parrot room was still closed. A release from quarantine for the parrot section was received from the District of Columbia Health Department on September 27, 1941, and the room was reopened to visitors several days later.

Through splendid assistance and cooperation on the part of the United States Public Health Service and the District of Columbia Health Department this disease has been eradicated. Suspected birds that die are sent to the Public Health Service for examination, and for nearly a year the results of the examination have all been negative.

DEATHS

The principal losses for the past year have been of very old residents. A sulphur-crested cockatoo, which was presented by Richard and Harry Hunt, Bethesda, Md., April 19, 1890, before the present Zoo was actually established, died June 20, 1942, after 52 years and 2 months in the Zoo. It had been a pet of the Hunt family for 5 years before coming to the Park. It had come to the United States in a sailing ship around Cape Horn.

The female reticulated giraffe which had been received June 21, 1939, died April 24, 1942. Other losses by death of animals which also had been in the Zoo for long periods included an Alaska Peninsula bear in the collection 19 years; Baird's tapir, in the Zoo since May, 1924; and a Malay porcupine that had lived here for 22 years.

The American bald eagle, "Jerry," probably the most photographed bird in the world, died April 15, 1942. It had come as a gift from President Wilson and had been a Zoo resident for 26 years. Photographs of "Jerry" were used as models for the eagle on our defense posters.

As usual, all specimens of scientific value that died during the year were sent to the National Museum

SPECIES NEW TO THE HISTORY OF THE COLLECTION

Very few exotic specimens were acquired during the year, and these were mainly replacements. The collection was augmented by the addition of three different types of cattle which had never been exhibited here before They were a Texas longhorn steer, a pair of British Park cattle, and a pair of West Highland or Kyloe cattle.

How acquired	Mammals	Birds	Reptiles	Amphibians	Fishes	Total
Presented	90	80	86	14	2	272
Born or hatched	65	40	2			107
Received in exchange	10	23	9			42
Purchased	24	107	100		42	273
On deposit	18	7	8			33
Collected by National Zoological Park staff	28			10		38
Total	235	257	205	24	44	765

Summary

Animals on hand July 1, 1941	2,380
Accessions during the year	765
Total animals in collection during year	3,145
Removal from collection by death, exchange, and return of animals on deposit	734
In collection June 30, 1942	2,411

Status of collection

Class	Species	Individuals	Class	Species	Individuals
Mammals	228	704	Insects	1	25
Birds	332	945	Mollusks	1	1
Reptiles	110	530	Crustaceans	1	3
Amphibians	17	68	Total	722	2,411
Fishes	30	132			
Arachnids	2	2			

Respectfully submitted.

W. M. Mann, *Director.*

Dr. C. G. Abbot,

Secretary, Smithsonian Institution.

APPENDIX 8

REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: I have the honor to submit the following report on the activities of the Astrophysical Observatory for the fiscal year ended June 30, 1942:

WORK AT WASHINGTON

PUBLICATION OF VOLUME 6 OF THE ANNALS

The outstanding event was the completion and publication of volume 6 of the Annals of the Observatory. The volume begins with extracts from these reports continuing the annals of the Observatory operations from 1931 to 1940. Next, the principal research on the variation of the sun's radiation is minutely described, with illustrative graphical and tabular matter relating to every feature. Then follow 78 quarto tabular pages giving in detail daily results of observation of the solar constant of radiation (i. e., the intensity of the sun's rays as they exist at mean solar distance outside the earth's atmosphere). This table covers all observations over the interval from 1923 to 1939 at Montezuma, Chile; Table Mountain, Calif.; and Mount St. Katherine, Egypt. The results are given in 12 columns for each day, covering not only the final results at each station, but the more important observations leading up to them. For some individual dates as many as 12 lines are required. Each page of the Annals includes 3 such groups of columns or 36 in all, and each page has approximately 80 lines. The enormous task of preparing this table has been mentioned repeatedly in preceding reports.

Then follows a chapter on the derived results and conclusions based on this great tabular compilation, and including related additional information for the years 1920 to 1923, derived from volume 5 of the Annals.

As regards accuracy, the probable accidental error of a single day's determination of the solar constant from observations at the stations is one-sixth of 1 percent, and for 10-day and monthly means, it is one-ninth and one-twentieth of 1 percent, respectively.

The variation of the sun, as our life-supporting star, is clearly indicated and between extreme ranges up to about 3 percent for the interval 1920 to 1939. It is verified not only by comparisons of our

own radiation observations at widely separated stations but by comparison of them with the publications of visual and photographic studies of the sun's surface made at other observatories. Such comparisons show, for instance, that the rotation of the sun upon its axis in the approximate period of 27 days frequently is attended by 1 percent change in solar radiation associated with well-marked changes in the visual and photographic appearance of the sun.

The variation of the sun is shown not to be of uniform percentage for all colors and wave lengths, but to increase rapidly in percentage toward the shorter wave lengths of the violet and ultraviolet rays. For ultraviolet rays of wave length 3500 angstroms, the percentage variation is 6 times as great as for the solar radiation as a whole.

Fourteen simultaneously operative regular periodicities are found in solar radiation ranging from 8 months to 273 months in periods. Each of these is reflected in temperatures and precipitations recorded by meteorological observations of official weather services. Long records, extending for 140 years, like those of Copenhagen, Vienna, and New Haven, prove that the 14 solar periodic variations have continued in unchanged phases, though perhaps not in unchanged amplitudes, during all that interval. Assuming that the phases will continue unchanged, and the amplitudes will be the average of amplitudes since 1920, a prediction of the solar variation to 1945 is hazarded.

The publication of volume 6 of the Annals, in such beautiful form and at so early a date, was made possible by funds generously supplied by Mr. John A. Roebling. Without his long-continued and munificent support and advice, the research could not have reached this satisfactory fruition. It is greatly hoped that it will furnish valuable aids to the science of meteorology.

TRANSFER OF THE DIVISION OF RADIATION AND ORGANISMS

A second outstanding event of the year is the acceptance by the Bureau of the Budget and the Congress of the proposal, strongly recommended by the Regents of the Institution, that the Division of Radiation and Organisms, hitherto for 13 years supported by private funds, and hitherto concerned with the fundamental study of plant growth, be incorporated as a branch of the Astrophysical Observatory. Since the beginning of the fiscal year 1942, this interesting fundamental research has been supported by Congressional appropriations, and its staff has been a part of the Government Civil Service.

INSTRUMENTS

Our detailed studies of the observations of the solar radiation disclosed, as above said, that the percentage variation of the intensity of the sun's rays is six times as great for ultraviolet rays as for the

total of all wave lengths. It also appeared plainly that the chief source of error remaining in the determinations arises from uncertainty of the exact effect of absorption in the great infrared water-vapor bands, occurring in a spectral region where solar variation is almost nil.

These considerations led the Director to devise a method whereby with a few additional observations using special glass absorbing screens determinations of solar variation could be restricted to the spectral region of the green, blue, violet, and ultraviolet rays. Apparatus for such determinations was prepared at our Washington instrument shop and has been installed at all three of the field stations. It has been in regular use at all of them since about July 1941 in addition to the ordinary observing.

It also appeared that certain types of sky conditions tended to produce unsatisfactory results by our present usual methods of observing the solar constant of radiation. It seemed possible that if in addition to our usual measurements we should observe the degree of polarization prevailing in sky light a correction of value might be discovered and applied in our daily measurements. Accordingly three copies of a sky polarization device invented by the late Prof. E. C. Pickering have been prepared at our Washington instrument shop. One is already installed at Montezuma, Chile, and has been used regularly since March 1942. Such instruments will soon be in use at our other stations.

Considerable special confidential work for military purposes has been done at our Washington instrument shop under the care of the Director.

The Assistant Director, Mr. L. B. Aldrich, has devoted a good deal of time as a member of the Smithsonian War Committee.

FIELD WORK

Three solar radiation observing stations have been operated on all favorable days at Table Mountain, Calif., Burro Mountain, N. Mex. (called the Tyrone station), and at Montezuma, Chile. The meteorological conditions have been rather less favorable than usual at all three stations, but still solar-constant observations were made on a majority of days at all stations.

New reinforced concrete dwelling quarters for the director's family at Montezuma were completed under field director Freeman's direction and finished shortly before he was relieved by A. F. Moore in July 1941, and in May 1942 the assistant's quarters were rebuilt to a considerable extent.

Improvements were also made at Table Mountain and Tyrone stations. A new water supply was installed at the former, and the drainage of the observing tunnel was perfected at the latter.

PERSONNEL CHANGES

A. Kramer, instrument maker, retired, was restored to the active Civil Service at Washington under war regulations on March 16, 1942. A. F. Moore relieved H. B. Freeman, resigned, at Montezuma as field director in July 1941, and F. A. Greeley relieved James H. Baden as bolometric assistant there in April 1942. W. H. Hoover continued as field director at Tyrone station, relieving A. F. Moore. Thomas Hassard served from October 6, 1941, to April 16, 1942, as bolometric assistant at Table Mountain, relieving F. A. Greeley. On Hassard's resignation to enter military service, he was followed by Kenneth G. Bower in May 1942. Miss N. M. McCandlish, special assistant to the Director, resigned March 1942.

The following members of the staff of the Division of Radiation and Organisms were transferred to the staff of the Astrophysical Observatory on July 1, 1941, under authorization of the Civil Service Commission: Robert M. Clagett, Leland B. Clark, Earl S. Johnston, Edward D. McAlister, and Robert L. Weintraub.

Respectfully submitted.

C. G. Abbot, *Director.*

The Secretary,
Smithsonian Institution.

APPENDIX 9

REPORT ON THE DIVISION OF RADIATION AND ORGANISMS

SIR: I have the honor to submit the following report on the activities of the Division of Radiation and Organisms during the year ended June 30, 1942:

Many changes have taken place in both personnel and physical equipment of the Division of Radiation and Organisms during the past year. Members of the Division were given Civil Service status on July 1, 1941, and the work is now carried on from appropriations allotted to the Astrophysical Observatory. The laboratory has been remodeled and most of the rooms repainted. The removal of the pipe shop to the United States National Museum made available much needed space and has relieved the crowded condition that existed. These changes brought about considerable temporary disruption in the regular work.

Different members of the Division have contributed directly or indirectly to work pertaining to war activities. The regular research work may, for convenience, be placed under three group headings: Photosynthesis, plant growth and radiation, and development of apparatus and methods.

Dr. Jack E. Myers continued his work with algae on problems related to photosynthesis until the expiration of his National Research Fellowship grant in September. He devised a method for the continous culture of algae with equipment built in the Division's laboratory. This apparatus he took with him to continue the work at the University of Texas as a cooperative project with our Division. The bearing this work has on our general program is that of obtaining uniform biological material that will give reproducible results under similar experimental conditions.

Mrs. Florence Meier Chase completed her study on the economic uses of algae and submitted a paper covering the subject for publication in the Smithsonian Annual Report for 1941.

Dr. Weintraub has completed a comprehensive review of the literature on plant respiration as affected by radiation. This was requested by Botanical Review, a journal which specializes in the publication of comprehensive technical reviews in the botanical field. This review is especially useful as a background in some of our investigations.

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Drs. Johnston and Weintraub have continued their experiments on the factors that influence the change in rates of respiration. This, of course, is basic work to our main project on photosynthesis. Our results lead one to speculate on the possibility of the existence of a carbon dioxide reservoir connected with the cell mechanism. It would seem that when the plants are conditioned in air of high carbon dioxide content a certain amount of excess carbon dioxide is stored in the tissue so that subsequent measurements of "apparent respiration" would consist of the carbon dioxide liberated by true respiration and that released from a well-filled reservoir. If, however, the plants are conditioned in air with little or no carbon dioxide the hypothetical reservoir is in a partially depleted condition and the first few periods of "apparent respiration" show a gradual increase in rate. This would be caused by the trapping in the reservoir of less and less of the respired carbon dioxide, thereby liberating more and more carbon dioxide which could be detected in the atmosphere surrounding the plant.

Such a reservoir hypothesis, however, is not sufficient to account for all the results obtained. There is evidence in much of our data that the humidity of the air plays an important role in this gaseous exchange, perhaps in changing the size of stomatal openings. Just what mechanism is involved in these plant responses is not yet clear. The answer must await improvements of the humidity controls of the apparatus. Such improvements are now being undertaken.

The relationship previously found by Dr. Weintraub between light intensity and inhibition of growth of the oats mesocotyl suggests that two growth processes are influenced by light; one alone at low intensities and both together at higher intensities. It appears likely that these two processes are cell elongation and cell division, respectively. In order to determine the action spectra for the two processes, and so to obtain an insight into their mechanisms, information on the intensity relations in various spectral regions is required. Such information has previously been obtained for a number of wave bands at low intensities, using a double monochromator. In extending the study to higher intensities, this method is not feasible and use must be made of emission spectra furnishing lines of adequate intensity and purity. Such lines as are available are now being studied over a wide intensity range and the plant material is being preserved for future histological study.

The action spectrum (maximum activity in the red) found for the mesocotyl inhibition at low intensities indicates the presence in the etiolated plant of a photoreceptive pigment possessing a similar absorption spectrum. An attempt to isolate such a pigment has been begun. The evidence thus far obtained points to the occurrence in the dark-grown oats seedling of traces of at least two pigments having

absorption bands in the red region of the spectrum. Work on the isolation and separation of these pigments is now in progress.

In view of the previous finding by Drs. Johnston and Weintraub, using the spectrographic method, that illumination increases the rate of carbon dioxide production by etiolated barley seedlings, it is of considerable interest to study the influence of radiation on the respiration of other types of plants. For this purpose the Warburg manometric technique seems well adapted, since both oxygen absorption and carbon dioxide evolution can be measured simultaneously. The necessary apparatus is being assembled and preliminary experiments to find suitable types of plant material and appropriate cultural conditions are under way. The data in the literature as well as results already obtained in this laboratory indicate that the effects of radiation on respiration may be intimately related to the previous cultural history of the plant.

PERSONNEL

Dr. Jack E. Myers, whose National Research Fellowship grant terminated in September, has been appointed assistant professor in the department of zoology and physiology at the University of Texas.

Mrs. Florence Meier Chase, who has been with the Division for 10 years, resigned on September 9.

On October 1 the services of Dr. E. D. McAlister were transferred to the Carnegie Institution of Washington for the purpose of carrying on war work.

Leonard Price was appointed junior physical science aid on February 16, 1942.

Mrs. Phyllis W. Prescott was appointed junior clerk-stenographer on March 24, 1942.

PUBLICATIONS

Johnston, Earl S. Demonstration of the effect of radiation on organisms at the Smithsonian Institution. Scientific Monthly, vol. 53 (July), pp. 92-96, 1941.

Weintraub, Robert L., and McAlister, Edward D. Developmental physiology of the grass seedling. I. Inhibition of the mesocotyl of *Avena sativa* by continuous exposure to light of low intensity. Smithsonian Misc. Coll., vol. 101, No. 17, pp. 1–10, 1942.

Respectfully submitted.

Earl S. Johnston, *Assistant Director.*

Dr. C. G. Abbot,
Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the Smithsonian Library for the fiscal year ended June 30, 1942:

War's initial impact upon the normal activities of a scientific library is disconcerting and disruptive. Publication of new material in the combatant countries declines, and such books and periodicals as are issued are obtainable with difficulty, if indeed they can be obtained at all. In the important scientific journals gaps appear and widen. As a consequence, service to readers becomes more limited. The whole immediate outlook for growth and accomplishment is discouraging.

Since September 1939 the Smithsonian Library has suffered in common with all other libraries of international scope, and as long as the war lasts it must continue to suffer from this negative influence which progressively decreases the inflow of material important for the work of the Institution and its branches. After Pearl Harbor came the final cutting off of all importations from enemy and occupied countries. The disruptive effect upon the normal activity of the library is graphically illustrated by the fact that during the fiscal year just ended 425 packages were received from abroad through the International Exchange Service, whereas in a recent pre-war year the number was 2,194.

Recovery from this serious crippling of the library's facilities will be slow, and the work of repair and of rebuilding will constitute a challenge to diligence and ingenuity during post-war years.

Fortunately, there is a positive, constructive, and much brighter side to the year's activities. Especially is this true of the library's relation to the war effort. The primary purpose of the library in normal times is service to the Institution's many specialists engaged in a wide range of studies covering the natural and physical sciences. A basic requirement for progress in any line of science is constant access to the published results of research in all countries. The large body of scientific literature accumulated in the years since the foundation of the Institution for the special needs of its staff has been found to provide valuable material of great importance to the various war agencies. As a result of this there has been a large increase in

the reference use of the library, especially in the branch library in the National Museum, including both personal visits and requests by telephone for information. This has also increased the loan to outside libraries, which were 218 more than last year.

In addition to providing access to published material and recorded information, the library has been able to extend its war reference service by putting inquirers directly in touch with members of the staff of the Institution having special professional or personal knowledge of various subjects. By knowing where, how, and from whom information not available in the Institution itself may be obtained, the library has also been enabled to arrange valuable introductions to outside sources. This kind of service, through which the library functions not only as a bibliographical center, but also as a general clearinghouse for information, is expanding and offers promising possibilities for more extensive future assistance in the war effort.

Upon recommendation of the Smithsonian War Committee and as a part of the Institution's program for directing its activities more definitely to the war effort, the library was instructed by the Secretary in April to prepare an index of the foreign geographical illustrations that have appeared in Smithsonian publications. Work was begun immediately, and before the end of the fiscal year the indexing of the Smithsonian Explorations and Field-Work series had been completed and work begun on other publications. Records of some 2,000 illustrations have been made and filed both alphabetically and by regions.

In spite of the time given to special war activities, routine duties of the library were well kept up. The acquisition of new material by purchase and exchange, the cataloging of books, the entering of periodicals, the preparation of volumes for binding, the keeping of loan-desk records, all are exact and time-consuming processes, upon which the smooth functioning of the library depends. Statistics of them, so far as they can be measured statistically, will be found at the end of this report.

Routine reference work for the staff of the Institution, and the use of books within the various libraries, of which no numerical count is attempted, continued to be heavy.

Although considerably handicapped by a temporarily curtailed staff, the decrease in the number of accessions from Europe and Asia has made it possible for the catalogers to devote some small part of their time to the recataloging of older material that has long needed attention. Full use of many of our most valuable series of publications has always been difficult because analysis of them has never been made for the catalog. Accurate identification of references and prompt delivery of material wanted are basic to good library service, especially from the loan desk, and they are largely dependent upon

good cataloging. It is hoped, as one of the compensations for the decrease in foreign accessions, to be able to continue and extend this program for making our already acquired resources more fully and easily usable.

In the matter of exchanges, a comparable program is in progress. With no immediate possibility of filling gaps in our files of foreign serials from sources abroad in direct exchange for our own publications, we are using, and are studying how to make further use of, our large and valuable duplicate collection for strengthening and extending our domestic exchanges. Lists of desiderata exchanged with other institutions are bringing good results in finding parts needed to complete incomplete serial files in all the participating libraries. Many of our duplicates, too, are given directly to other Government libraries that need them. Notably, in response to a request from the Scientific Library of the Patent Office, we were able this year to supply 1,524 parts of periodicals lacking in their sets.

GIFTS

Friends and patrons made generous gifts to the library. The Secretary, the Assistant Secretary, and other members and collaborators of the Smithsonian staff contributed many publications. The American Museum of Natural History, the Boston Museum of Fine Arts, and other institutions with which we are regularly in exchange made us special gifts in addition. From the American Association for the Advancement of Science came 724 publications, and 68 were received from the American Association of Museums. A noteworthy gift, numbering some 2,000 items, was the library on Copepoda assembled by the late Dr. Charles Branch Wilson and presented by his son, Carroll A. Wilson, to the Division of Marine Invertebrates. A card index for use with the collection accompanied it. Of special interest was Mrs. Cyrus Adler's gift of the posthumously published book, I Have Remembered the Days, the autobiography of the late Dr. Cyrus Adler, formerly librarian of the Institution. Other donors were, Percy S. Alden, Theodore Bolton, Willard C. Brinton, L. V. Coleman, Dr. P. T. Collinge, Miss Elsie G. Curry, Dr. Carl Epling, Mrs. Paul Garber, The Board of Directors of the Golden Gate Bridge and Highway District, Dr. John M. Hiss, R. G. Ingersoll Waite, Prof. James R. Jack, Dr. Thomas H. Kearney, Dr. Riley D. Moore, Dr. W. L. McAtee, The National Society of Colonial Dames of America, Dr. T. L. Northup, Mrs. Foster Stearns, Prof. Theodore Sizer.

PERSONNEL

Most important of the unusually large number of changes on the staff was the retirement of William L. Corbin as librarian on January 31, 1942, after more than 17 years of service. Coming to the Institution in the early years after the First World War, he was confronted with many difficult tasks of rehabilitation and administration. He gave his best efforts to the completion of important files of scientific journals broken by the war, to the reestablishment and extension of exchange relationships and to the building up of an efficient library personnel for the service of the Institution.

On February 2, 1942, Mrs. Leila F. Clark, who had been assistant librarian in charge of the National Museum library since 1929, was appointed librarian of the Institution.

Miss Elisabeth P. Hobbs, head cataloger, was promoted on May 21, 1942, to the position of associate librarian in charge of the Museum library. Mrs. Lucile Torrey Barrett, who had given exceptional service as librarian of the National Collection of Fine Arts, was transferred to a war agency on February 23, 1942. Other changes were the resignation of Miss Ruth Blanchard on October 31, 1941, and the appointments of Miss Marjorie Kunze and Miss Marion Blair on January 5, 1942. The temporary appointments of Mrs. Georgeanna H. Morrill and Mrs. Clara Dick, made during the preceding fiscal year, were terminated on December 31, 1941. Assistant messengers for short periods were Arthur Gambrell and John Barnes. Samuel Jones, who is now serving, was appointed May 5.

STATISTICS

The accessions to the libraries were as follows:

Accessions

	Volumes	Pamphlets	Total	Approximate holdings June 30, 1942
Astrophysical Observatory	172	71	243	10,309
Freer Gallery of Art	74	67	141	16,366
Langley Aeronautical	20	6	26	3,573
National Collection of Fine Arts	191	114	305	7,904
National Museum	2,503	1,024	3,527	222,287
National Zoological Park	12	13	25	3,941
Radiation and Organisms	9	1	10	808
Smithsonian Deposit, Library of Congress	892	423	1,315	669,977
Smithsonian Office	61	33	94	21,635
Total	3,934	1,751	5,685	[1] 957,200

[1] This figure does not include incomplete volumes of periodicals or separates and reprints from periodicals.

Exchanges

New exchanges arranged:	
For the Smithsonian Deposit	84
For the National Museum library	127
For other branch libraries	18
Total	229
"Wants" received:	
For the Smithsonian Deposit	1,132
For the National Museum library	2,286
For other branch libraries	622
Total	4,040
Letters written	1,581

Cataloging

Volumes and pamphlets cataloged	4,775
Cards filed in catalogs and shelflists	20,826

Other Activities

Periodicals entered	12,258
Loans of books and periodicals	9,078
Volumes sent to the bindery	1,400

Respectfully submitted.

Leila F. Clark, *Librarian.*

Dr. C. G. Abbot,
Secretary, Smithsonian Institution.

APPENDIX 11

REPORT ON PUBLICATIONS

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and the Government branches under its administrative charge during the year ended June 30, 1942:

The Institution published during the year 18 papers in the Smithsonian Miscellaneous Collections, and title page and table of contents of volumes 73 and 99 of this series; 2 papers in the War Background Studies series; 1 Annual Report and pamphlet copies of 23 articles in the Report appendix; and 3 special publications. Additional copies of two volumes of the Smithsonian's series of tables were also printed.

The United States National Museum issued 1 Annual Report; 36 Proceedings papers; 3 Bulletins and 1 part each of 3 Bulletins; 1 separate paper in the Bulletin series of Contributions from the United States National Herbarium.

The Bureau of American Ethnology issued 1 Annual Report and 3 Bulletins.

The Astrophysical Observatory issued volume 6 of the Annals of the Astrophysical Observatory.

Of the publications there were distributed 162,525 copies, which included 17 volumes and separates of the Smithsonian Contributions to Knowledge, 37,650 volumes and separates of the Smithsonian Miscellaneous Collections, 22,052 volumes and separates of the Smithsonian Annual Reports, 1,245 War Background Studies papers, 2,575 Smithsonian special publications, 82,545 volumes and separates of National Museum publications, 11,631 publications of the Bureau of American Ethnology, 6 publications of the National Collection of Fine Arts, 3 publications of the Freer Gallery of Art, 14 reports on the Harriman Alaska Expedition, 1,362 Annals of the Astrophysical Observatory, and 383 reports of the American Historical Association.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

There were issued title page and table of contents of volumes 73 and 99, 3 papers of volume 99, 15 papers of volume 101, and reprints of volumes 86 and 88, as follows:

VOLUME 73

Title page and table of contents. (Publ. 3648.) December 16, 1941.

VOLUME 99

No. 8. Check-list of the terrestrial and fresh-water Isopoda of Oceania, by H. Gordon Jackson. 35 pp. (Publ. 3593.) July 23, 1941.

No. 22. The ice age problem, by Walter Knoche. 5 pp. (Publ. 3633.) July 30, 1941.

No. 23. Evidences of early occupation in Sandia Cave, New Mexico, and other sites in the Sandia-Manzano region, by Frank C. Hibben, with appendix on Correlation of the deposits of Sandia Cave, New Mexico, with the glacial chronology, by Kirk Bryan. vi+64 pp., 15 pls., 9 figs. (Publ. 3636.) October 15, 1941.

Title page and table of contents. (Publ. 3644.) November 13, 1941.

VOLUME 101

No. 2. A new salamander of the genus *Gyrinophilus* from the southern Appalachians, by M. B. Mittleman and Harry G. M. Jopson. 5 pp., 1 pl. (Publ. 3638.) July 14, 1941.

No. 3. Environment and native subsistence economies in the central Great Plains, by Waldo R. Wedel. 29 pp., 5 pls., 1 fig. (Publ. 3639.) August 20, 1941.

No. 4. Diseases of and artifacts on skulls and bones from Kodiak Island, by Aleš Hrdlička. 14 pp., 11 pls. (Publ. 3640.) September 23, 1941.

No. 5. On solar-constant and atmospheric temperature changes, by Henryk Arctowski. vi+62 pp., 33 figs. (Publ. 3641.) November 7, 1941.

No. 6 Beetles of the genus *Hyperaspis* inhabitating the United States, by Th. Dobzhansky. 94 pp., 6 pls. (Publ. 3642.) December 31, 1941.

No. 7. Archeological remains in central Kansas and their possible bearing on the location of Quivira, by Waldo R. Wedel. 24 pp., 10 pls., 1 fig. (Publ. 3647.) January 15, 1942.

No. 8. Bees of the family Hylaeidae from the Ethiopian region, by T. D. A. Cockerell. 15 pp. (Publ. 3649.) February 19, 1942.

No. 9. Notes on some American fresh-water amphipod crustaceans and descriptions of a new genus and two new species, by Clarence R. Shoemaker. 31 pp., 12 figs. (Publ. 3675.) February 16, 1942.

No. 10. Faunal content of the Maryville formation, by Charles E. Resser. 8 pp. (Publ. 3676.) February 13, 1942.

No. 11. Amphipod crustaceans collected on the Presidential Cruise of 1938, by Clarence R. Shoemaker. 52 pp., 17 figs. (Publ. 3677.) March 5, 1942.

No. 12. The quantity of vaporous water in the atmosphere, by C. G. Abbot. 7 pp. (Publ. 3678.) March 23, 1942.

No. 13. A new titanothere from the Eocene of Mississippi, with notes on the correlation between the marine Eocene of the Gulf Coastal Plain and continental Eocene of the Rocky Mountain region, by C. L. Gazin and J. Magruder Sullivan. 13 pp., 3 pls., 1 fig. (Publ. 3679.) April 23, 1942.

No. 14. Two new fossil birds from the Oligocene of South Dakota, by Alexander Wetmore. 6 pp., 13 figs. (Publ. 3680.) May 11, 1942.

No. 15. Fifth contribution to nomenclature of Cambrian fossils, by Charles E. Resser. 58 pp. (Publ. 3682.) May 22, 1942.

No. 17. Developmental physiology of the grass seedling. I. Inhibition of the mesocotyl of *Avena sativa* by continuous exposure to light of low intensities, by Robert L. Weintraub and Edward D. McAlister. 10 pp., 1 pl., 4 figs. (Publ. 3685.) June 24, 1942.

Additional copies of the following two volumes were printed:

VOLUME 86

Smithsonian Meteorological Tables, Fifth Revised Edition, First Reprint. lxxxvi+282 pp. (Publ. 3116.)

VOLUME 88

Smithsonian Physical Tables, Eighth Revised Edition, First Reprint. liv+686 pp. (Publ. 3171.)

WAR BACKGROUND STUDIES

In the new series of Smithsonian publications, War Background Studies, the following papers were issued:

No. 1. Origin of the Far Eastern civilizations: a brief handbook, by Carl Whiting Bishop. 53 pp., 12 pls., 21 figs. (Publ. 3681.) June 10, 1942.

No. 2. The evolution of nations, by John R. Swanton. 23 pp. (Publ. 3686.) June 24, 1942.

SMITHSONIAN ANNUAL REPORTS

Report for 1940.—The complete volume of the Annual Report of the Board of Regents for 1940 was received from the Public Printer in October 1941.

Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and condition of the Institution for the year ended June 30, 1940. xiii+512 pp., 107 pls., 28 figs. (Publ. 3606.)

The appendix contained the following papers:

Solar prominences in motion, by Robert R. McMath.
The satellites of Jupiter, by Seth B. Nicholson.
Cultural values of physics, by David Dietz.
Nuclear fission, by Karl K. Darrow.
The national standards of measurement, by Lyman J. Briggs.
The rise of the organic chemical industry in the United States, by C. M. A. Stine.
The rubber industry, 1839-1939, by W. A. Gibbons.
The future of man as an inhabitant of the earth, by Kirtley F. Mather.
The search for oil, by G. M. Lees.
Perspectives in evolution, by James Ritchie, M. A., D. Sc.
Animal behavior, by Ernest P. Walker.
The national wildlife refuge program of the Fish and Wildlife Service, by Ira N. Gabrielson.
A living fossil, by J. L. B. Smith.
Insects and the spread of plant diseases, by Walter Carter.
The Mexican bean beetle, by W. H. White.
Plant-tissue cultures, by Robert L. Weintraub.
The botany and history of *Zizania aquatica* L. ("wild rice"), by Charles E. Chambliss.
Prehistoric culture waves from Asia to America, by Diamond Jenness.
Masked medicine societies of the Iroquois, by William N. Fenton.
The beginnings of civilization in eastern Asia, by Carl Whiting Bishop.
Stonehenge: Today and yesterday, by Frank Stevens, O. B. E., F. S. A.
Sulfanilamide and related chemicals in the treatment of infectious diseases, by Wesley W. Spink, M. D.

The future of flying, by H. E. Wimperis, C. B., C. B. E., Hon. D. Eng. (Melb.), Past President Royal Aeronautical Society.

Report for 1941.—The Report of the Secretary, which included the financial report of the executive committee of the Board of Regents, and which will form part of the Annual Report of the Board of Regents to Congress, was issued in January 1942.

Report of the Secretary of the Smithsonian Institution and financial report of the executive committee of the Board of Regents for the year ended June 30, 1940. ix+136 pp., 5 pls., 2 figs. (Publ. 3648.)

The Report volume, containing the general appendix, was in press at the close of the year.

SPECIAL PUBLICATIONS

Handbook of the National Aircraft Collection, Fifth Edition, by Paul E. Garber. 43 pp., 26 pls., 1 fig. (Publ. 3635.) July 23, 1941.

Classified list of Smithsonian publications available for distribution December 1, 1941, compiled by Helen Munroe. 42 pp. (Publ. 3645.) December 11, 1941.

Brief guide to the Smithsonian Institution, Fifth Edition. 80 pp., 53 ills. (Publ. BL.) May 1942.

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum has continued during the year under the immediate direction of the editor, Paul H. Oehser. There were issued 1 Annual Report, 36 Proceedings papers, 6 Bulletins, and 1 separate paper in the Bulletin series of Contributions from the United States National Herbarium, as follows:

MUSEUM REPORT

Report on the progress and condition of the United States National Museum for the fiscal year ended June 30, 1941. iii+118 pp. January 1942.

PROCEEDINGS: VOLUME 87

Title page, table of contents, and index. Pp. i–viii, 635–672. September 16, 1941.

VOLUME 90

No. 3107. Revision of the North American moths of the family Oecophoridae, with descriptions of new genera and species, by J. F. Gates Clarke. Pp. 33–286, pls. 1–48. November 6, 1941.

No. 3109. A history of the division of vertebrate paleontology in the United States National Museum, by C. W. Gilmore. Pp. 305–377, pls. 49–53. August 5, 1941.

No. 3110. A new harpacticoid copepod from the gill chambers of a marsh crab, by Arthur G. Humes. Pp. 379–385, fig. 18. August 5, 1941.

No. 3112. Cestode parasites of teleost fishes of the Woods Hole region, Massachusetts, by Edwin Linton. Pp. 417–442, pls. 60–62. July 15, 1941.

No. 3113. Pamlico fossil echinoids, by Willard Berry. Pp. 443–445, pls. 63–65. July 5, 1941.

No. 3115. Notes on Mexican turtles of the genus *Kinosternon*, by Leonhard Stejneger. Pp. 457–459. July 25, 1941.

No. 3116. A revision of the chalcid-flies of the genus *Monodontomerus* in the United States National Museum, by A. B. Gahan. Pp. 461–482. August 19, 1941.

No. 3117. Notes on the birds of North Carolina, by Alexander Wetmore. Pp. 483–530. October 31, 1941.

No. 3118. Notes on some North and Middle American danaid butterflies, by Austin H. Clark. Pp. 531–542, pls. 71–74. November 4, 1941.

No. 3119. A new genus of psammocharid wasp from China, by P. P. Babiy. Pp. 543–546, fig. 23. October 24, 1941.

No. 3120. Two new species of Cecidomyiid flies from *Phlox*, by Charles T. Greene. Pp. 547–551, fig. 24. October 30, 1941.

VOLUME 91

No. 3121. The mammalian faunas of the Paleocene of central Utah, with notes on the geology, by C. Lewis Gazin. Pp. 1–53, figs. 1–29, pls. 1–3. October 2, 1941.

No. 3122. A new fossil crocodilian from Colombia, by Charles C. Mook. Pp. 55–58, pls. 4–9. January 17, 1942.

No. 3123. The North American moths of the genus *Arachnis*, with one new species, by J. F. Gates Clarke. Pp. 59–70, pls. 10–12. November 14, 1941.

No. 3124. Some little-known fossil lizards from the Oligocene of Wyoming, by Charles W. Gilmore. Pp. 71–76, figs. 30–32. November 13, 1941.

No. 3125. New species of hydroids, mostly from the Atlantic Ocean, in the United States National Museum, by C. McLean Fraser. Pp. 77–89, pls. 13–18. November 14, 1941.

No. 3126. The Nevada early Ordovician (Pogonip) sponge fauna, by R. S. Bassler. Pp. 91–102, pls. 19–24. November 1, 1941.

No. 3127. The Mexican subspecies of the snake *Coniophanes fissidens*, by Hobart M. Smith. Pp. 103–111, fig. 33. November 13, 1941.

No. 3128. Report on the Smithsonian-Firestone expedition's collection of reptiles and amphibians from Liberia, by Arthur Loveridge. Pp. 113–140, fig. 34. November 14, 1941.

No. 3129. Notes on some crayfishes from Alabama caves, with the description of a new species and a new subspecies, by Rendell Rhoades. Pp. 141–148, figs. 35, 36. November 6, 1941.

No. 3130. Notes on the snake genus *Trimorphodon*, by Hobart M. Smith. Pp. 149–168, figs. 37, 38. November 10, 1941.

VOLUME 92

No. 3133. Notes on two genera of American flies of the family Trypetidae, by John R. Malloch. Pp. 1–20, fig. 1. January 7, 1942.

No. 3134. The Freda, N. Dak., meteorite: A nickel-rich ataxite, by E. P. Henderson and Stuart H. Perry. Pp. 21–23, pls. 1–4. March 23, 1942.

No. 3135. Some cestodes from Florida sharks, by Asa C. Chandler. Pp. 25–31, figs. 2, 3. February 9, 1942.

No. 3136. A new species of phyllopod crustacean from the southwestern short-grass prairies, by J. G. Mackin. Pp. 33–39, figs. 4–6. April 15, 1942.

No. 3137. Descriptions of five new species of Chalcidoidea, with notes on a few described species (Hymenoptera), by A. B. Gahan. Pp. 41–51. March 4, 1942.

No. 3138. A new stomatopod crustacean from the west coast of Mexico, by Steve A. Glassell. Pp. 53–56, fig. 7. March 26, 1942.

No. 3139. The chrysomelid beetles *Luperodes bivittatus* (LeConte) and *varicornis* (LeConte) and some allied species, by Doris H. Blake. Pp. 57-74, pls. 5, 6. April 7, 1942.

No. 3140. Notes on the classification of the staphylinid beetles of the groups Lispini and Osoriinae, by Richard E. Blackwelder. Pp. 75-90. April 7, 1942.

No. 3141. Scored bone artifacts of the central Great Plains, by W. R. Wedel and A. T. Hill. Pp. 91-100, pls. 7-13. April 28, 1942.

No. 3142. The identity of some marine annelid worms in the United States National Museum, by Olga Hartman. Pp. 101-140, figs. 8-15. June 10, 1942.

No. 3143. The Sardis (Georgia) meteorite, by E. P. Henderson and C. Wythe Cooke. Pp. 141-150, pls. 14, 15. April 30, 1942.

No. 3144. *Rhopocrinus*, a new fossil inadunate crinoid genus, by Edwin Kirk. Pp. 151-155, pl. 16. April 24, 1942.

No. 3145. Notes on beetles related to *Phyllophaga* Harris, with descriptions of new genera and subgenera, by Lawrence W. Saylor. Pp. 157-165, pl. 17. June 11, 1942.

No. 3146. Descriptions of the larvae of some West Indian melolonthine beetles and a key to the known larvae of the tribe, by Adam G. Böving. Pp. 167-176, pls. 18, 19. June 13, 1942.

BULLETINS

No. 50, part 9. The birds of North and Middle America. Families Gruidae, Rallidae, Heliornithidae, and Eurypygidae, by Robert Ridgway and Herbert Friedmann. ix+254 pp., 16 figs. October 2, 1941.

No. 82, volume 1, part 4a. A monograph of the existing crinoids. The superfamily Mariametrida (except the family Colobometridae), by Austin H. Clark. vii+603 pp., 61 pls. August 5, 1941.

No. 161, part 3. The Foraminifera of the tropical Pacific collections of the "Albatross," 1899-1900. Heterohelicidae and Buliminidae, by Joseph Augustine Cushman. x+67 pp., 15 pls. February 10, 1941.

No. 177. The herpetology of Hispaniola, by Doris M. Cochran. vii+398 pp., 12 pls. July 8, 1941.

No. 178. Catalog of the type specimens of mammals in the United States National Museum, including the Biological Surveys collection, by Arthur J. Poole and Viola S. Schantz. xiii+705 pp. April 8, 1942.

No. 179. Life histories of North American flycatchers, larks, swallows, and their allies, by Arthur Cleveland Bent. xi+555 pp., 70 pls. May 8, 1942.

CONTRIBUTIONS FROM THE U. S. NATIONAL HERBARIUM: VOLUME 28

Part 4. Plants collected by R. C. Ching in southern Mongolia and Kansu Province, China, by E. H. Walker. xiii+675 pp., pls. 21-27. July 22, 1941.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau has continued under the immediate direction of the editor, M. Helen Palmer. During the year there were issued 1 Annual Report and 3 Bulletins, as follows:

REPORT

Fifty-eighth annual report of the Bureau of American Ethnology, 1940-1941. 13 pp. February 11, 1942.

BULLETINS

129. An archeological survey of Pickwick Basin in the adjacent portions of the States of Alabama, Mississippi, and Tennessee, by William S. Webb and David L. DeJarnette. With additions by Walter B. Jones, J. P. E. Morrison, Marshall T. Newman and Charles E. Snow, and William G. Haag. 536 pp., 316 pls., 99 figs. March 23, 1942.

130. Archeological investigations at Buena Vista Lake, Kern County, California, by Waldo R. Wedel. With appendix, Skeletal remains from the Buena Vista sites, California, by T. D. Stewart. 194 pp., 57 pls., 19 figs. July 14, 1941.

131. Peachtree Mound and village site, Cherokee County, North Carolina, by Frank M. Setzler and Jesse D. Jennings. With appendix, Skeletal remains from the Peachtree Site, North Carolina, by T. D. Stewart. 103 pp., 50 pls., 12 figs. October 9, 1941.

PUBLICATIONS OF THE ASTROPHYSICAL OBSERVATORY

With funds supplied by John A. Roebling, the Astrophysical Observatory was able to publish volume 6 of the Annals.

Annals of the Astrophysical Observatory of the Smithsonian Institution, Volume 6, by C. G. Abbot, L. B. Aldrich, and W. H. Hoover. viii+207 pp., 7 pls., 18 figs. (Publ. 3650.) April 24, 1942.

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the Association to the Secretary of the Smithsonian Institution and are communicated by him to Congress, as provided by the act of incorporation of the Association. The report for 1939 (Proceedings) was issued in October 1941. The following were in press at the close of the year: Report for 1936, volume 3 ("Instructions of the British Foreign Secretaries to their envoys in the United States, 1791–1812"); report for 1937, volume 2 (Writings in American History, 1937, 1938); report for 1939, volume 1 (Proceedings); report for 1940; and report for 1941, volume 1, and volume 2 (Talleyrand in America as a financial promoter, 1794–96).

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Forty-fourth Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, November 26, 1941.

ALLOTMENTS FOR PRINTING

The congressional allotments for the printing of the Smithsonian Annual Reports to Congress and the various publications of the Government bureaus under the administration of the Institution were

virtually used up at the close of the year. The appropriation for the coming year ending June 30, 1943, totals $88,500, allotted as follows:

Smithsonian Institution	$16,000
National Museum	43,000
Bureau of American Ethnology	17,480
National Collection of Fine Arts	500
International Exchanges	200
National Zoological Park	200
Astrophysical Observatory	500
American Historical Association	10,620
Total	88,500

Respectfully submitted.

W. P. True, *Chief, Editorial Division.*

Dr. C. G. Abbot,

Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

FOR THE YEAR ENDED JUNE 30, 1942

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution, together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

SMITHSONIAN ENDOWMENT FUND

The original bequest of James Smithson was £104,960 8s. 6d.—$508,318.46. Refunds of money expended in prosecution of the claim, freights, insurance, etc., together with payment into the fund of the sum of £5,015, which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of $550,000.

Since the original bequest the Institution has received gifts from various sources chiefly in the years prior to 1893, the income from which may be used for the general work of the Institution.

To these gifts has been added capital from savings on income, gain from sale of securities, etc., and they now stand on the books of the Institution as follows:

Avery, Robert S. and Lydia T., bequest fund	$51, 044. 98
Endowment fund, from gifts, income, etc	263, 743. 57
Habel, Dr. S., bequest fund	500. 00
Hachenberg, George P. and Caroline, bequest fund	4, 001. 06
Hamilton, James, bequest fund	2, 901. 61
Henry, Caroline, bequest fund	1, 203. 20
Hodgkins, Thomas G., fund	146, 067. 43
Parent fund	728, 854. 50
Rhees, William Jones, bequest fund	1, 060. 04
Sanford, George H., memorial fund	1, 985. 61
Witherspoon, Thomas A., memorial fund	128,385. 77
Special fund	1, 400. 00
Total endowment for general work of the Institution	1, 331, 153. 37

The Institution holds also a number of endowment gifts, the income of each being restricted to specific use. These are invested and stand on the books of the Institution as follows:

Abbott, William L., fund, bequest to the Institution	$103, 157. 88
Arthur, James, fund, income for investigations and study of the sun and lecture on the sun	39, 787. 45

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Bacon, Virginia Purdy, fund, for a traveling scholarship to investigate fauna of countries other than the United States	$49, 842. 89
Baird, Lucy H., fund, for creating a memorial to Secretary Baird	17, 538. 76
Barstow, Frederic D., fund, for purchase of animals for the Zoological Park	756. 76
Canfield Collection fund, for increase and care of the Canfield collection of minerals	38, 050. 18
Casey, Thomas L., fund, for maintenance of the Casey collection and promotion of researches relating to Coleoptera	9, 124. 91
Chamberlain, Francis Lea, fund, for increase and promotion of Isaac Lea collection of gems and mollusks	28, 015. 52
Hillyer, Virgil, fund, for increase and care of Virgil Hillyer collection of lighting objects	6, 538. 40
Hitchcock, Dr. Albert S., Library fund, for care of Hitchcock Agrostological Library	1, 413. 20
Hodgkins fund, specific, for increase and diffusion of more exact knowledge in regard to nature and properties of atmospheric air	100, 000. 00
Hughes, Bruce, fund, to found Hughes alcove	19, 042. 76
Myer, Catherine Walden, fund, for purchase of first-class works of art for the use of, and benefit of, the National Collection of Fine Arts	18, 853. 45
National Collection of Fine Arts, Strong Bequest	9, 946. 50
Pell, Cornelia Livingston, fund, for maintenance of Alfred Duane Pell collection	7, 374. 38
Poore, Lucy T. and George W., fund, for general use of the Institution when principal amounts to the sum of $250,000	84, 382. 57
Reid, Addison T., fund, for founding chair in biology in memory of Asher Tunis	29, 977. 61
Roebling fund, for care, improvement, and increase of Roebling collection of minerals	120, 067. 00
Rollins, Miriam and William, fund, for investigations in physics and chemistry	89, 495. 28
Smithsonian employees retirement fund	20, 893. 67
Springer, Frank, fund, for care, etc., of Springer collection and library	17, 840. 52
Walcott, Charles D. and Mary Vaux, research fund, for development of geological and paleontological studies and publishing results thereof	354, 214. 88
Younger, Helen Walcott, fund, held in trust	50, 112. 50
Zerbee, Frances Brincklé, fund, for endowment of aquaria	757. 15
Special research fund, gift, in the form of real estate	20, 946. 00
Total endowment for specific purposes other than Freer endowment	1, 238, 135. 22

The above funds amount to a total of $2,569,288.59, and are carried in the following investment accounts of the Institution:

U. S. Treasury deposit account, drawing 6 percent interest	$1, 000, 000. 00
Consolidated investment fund (income in table below)	1, 270, 968. 45
Real estate, mortgages, etc	246, 807. 64
Special funds, miscellaneous investments	51, 512. 50
	2, 569, 288. 59

CONSOLIDATED FUND

Statement of principal and income for the last 10 years

Fiscal year	Capital	Income	Percentage	Fiscal year	Capital	Income	Percentage
1933	$764,077.67	$28,185.11	3.68	1938	$867,528.50	$34,679.64	4.00
1934	734,670.84	26,650.22	3.65	1939	902,801.27	30,710.53	3.40
1935	709,705.69	26,808.80	3.79	1940	1,081,249.25	26,673.29	2.47
1936	723,795.46	26,830.61	3.71	1941	1,093,301.51	41,167.38	3.76
1937	738,858.54	33,819.43	4.57	1942	1,270,968.43	46,701.98	3.67

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other Oriental objects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for the construction of a building to house the collection, and finally in his will, probated November 6, 1919, he provided stock and securities to the estimated value of $1,958,591.42 as an endowment fund for the operation of the gallery. From the above date to the present time these funds have been increased by stock dividends, savings of income, etc., to a total of $5,912,878.64. In view of the importance and special nature of the gift and the requirements of the testator in respect to it, all Freer funds are kept separate from the other funds of the Institution, and the accounting in respect to them is stated separately.

The invested funds of the Freer bequest are classified as follows:

Court and grounds fund	$662,390.04
Court and grounds maintenance fund	166,381.00
Curator fund	674,088.94
Residuary legacy	4,410,038.66
Total	5,912,878.64

SUMMARY

Invested endowment for general purposes	$1,331,153.37
Invested endowment for specific purposes other than Freer endowment	1,238,135.22
Total invested endowment other than Freer endowment	2,569,288.59
Freer invested endowment for specific purposes	5,912,878.64
Total invested endowment for all purposes	8,482,167.23

CLASSIFICATION OF INVESTMENTS

Deposited in the U. S. Treasury at 6 percent per annum, as authorized in the United States Revised Statutes, sec. 5591		$1,000,000.00
Investments other than Freer endowment (cost or market value at date acquired):		
Bonds (24 different groups)	$474,228.77	
Stocks (52 different groups)	906,138.35	
Real estate and first-mortgage notes	182,762.64	
Uninvested capital	6,158.83	
		1,569,288.59
Total investments other than Freer endowment		2,569,288.59
Investments of Freer endowment (cost or market value at date acquired):		
Bonds (43 different groups)	$2,334,095.23	
Stocks (69 different groups)	3,469,025.55	
Real estate first-mortgage notes	8,000.00	
Uninvested capital	101,757.86	
		5,912,878.64
Total investments		8,482,167.23

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING THE FISCAL YEAR[1]

Cash balance on hand June 30, 1941		$497,141.14
Receipts:		
Cash income from various sources for general work of the Institution	$79,215.92	
Cash gifts and contributions expendable for special scientific objects (not to be invested)	38,100.00	
Cash gifts for special scientific work (to be invested)	28,073.85	
Cash income from endowments for specific use other than Freer endowment and from miscellaneous sources (including refund of temporary advances)	130,995.54	
Cash received as royalties from Smithsonian Scientific Series	18,173.47	
Cash capital from sale, call of securities, etc. (to be reinvested)	95,795.28	
Total receipts other than Freer endowment		390,354.06
Cash income from Freer endowment	$241,557.77	
Cash capital from sale, call of securities, etc. (to be reinvested)	899,670.48	
Total receipts from Freer endowment		1,141,228.25
Total		2,028,723.45

[1] This statement does not include Government appropriations under the administrative charge of the Institution.

Disbursements:		
From funds for general work of the Institution:		
Buildings—care, repairs, and alterations	$3,429.92	
Furniture and fixtures	509.63	
General administration [2]	30,215.61	
Library	1,346.62	
Publications (comprising preparation, printing, and distribution)	19,607.00	
Researches and explorations	6,444.42	
		$61,553.20
From funds for specific use, other than Freer Endowment:		
Investments made from gifts, from gain from sale, etc., of securities and from savings on income	65,478.47	
Other expenditures, consisting largely of research work, travel, increase and care of special collections, etc., from income of endowment funds, and from cash gifts for specific use (including temporary advances)	91,931.25	
Reinvestment of cash capital from sale, call of securities, etc	89,677.17	
Cost of handling securities, fee of investment counsel, and accrued interest on bonds purchased	2,394.50	
		249,481.39
From Freer Endowment:		
Operating expenses of the gallery, salaries, field expenses, etc	45,606.72	
Purchase of art objects	110,880.43	
Investments made from gain from sale, etc., of securities	11,246.70	
Reinvestment of cash capital from sale, call of securities, etc	790,392.39	
Cost of handling securities, fee of investment counsel, and accrued interest on bonds purchased	18,738.89	
		976,865.13
Cash balance June 30, 1942		740,823.73
Total		2,028,723.45

Included in the foregoing are expenditures for researches in pure science, publications, explorations, care, increase, and study of collections, etc., as follows:

Expenditures from general funds of the Institution:		
Publications	$19,607.00	
Researches and explorations	6,444.42	
		$26,051.42

[2] This includes salary of the Secretary and certain others.

Expenditures from funds devoted to specific purposes:		
Researches and explorations	$42, 855. 38	
Care, increase, and study of special collections	3, 253. 26	
Publications	4, 950. 98	
		$51, 059. 62
Total		77, 111. 04

The practice of depositing on time in local trust companies and banks such revenues as may be spared temporarily has been continued during the past year, and interest on these deposits has amounted to $263.06.

The Institution gratefully acknowledges gifts or bequests from the following:

> Research Corporation, further contributions for research in radiation.
> John A. Roebling, further contributions for research in radiation.
> Mary Vaux Walcott, bequest to augment the Charles D. and Mary Vaux Walcott research fund.

All payments are made by check, signed by the Secretary of the Institution on the Treasurer of the United States, and all revenues are deposited to the credit of the same account. In many instances deposits are placed in bank for convenience of collection and later are withdrawn in round amounts and deposited in the Treasury.

The foregoing report relates only to the private funds of the Institution.

The following annual appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1942:

General Expenses (including supplemental appropriation under the Ramspeck Act)	$390, 404
(This combines under one heading the appropriations heretofore made for Salaries and Expenses, International Exchanges, American Ethnology, Astrophysical Observatory, and National Collection of Fine Arts of the Smithsonian Institution, and for Maintenance and Operation of the United States National Museum.)	
Preservation of Collections (including supplemental appropriation under the Ramspeck Act)	636, 118
Printing and binding	88, 500
National Zoological Park	239, 260
Cooperation with the American Republics (transfer to the Smithsonian Institution)	56, 500
Total	1, 410, 782

The report of the audit of the Smithsonian private funds is given below:

SEPTEMBER 8, 1942.

EXECUTIVE COMMITTEE, BOARD OF REGENTS,
Smithsonian Institution, Washington, D. C.

SIRS: Pursuant to agreement we have audited the accounts of the Smithsonian Institution for the fiscal year ended June 30, 1942, and certify the balance of cash on hand, including Petty Cash Fund, June 30, 1942, to be $742,723.73.

We have verified the record of receipts and disbursements maintained by the Institution and the agreement of the book balances with the bank balances.

We have examined all the securities in the custody of the Institution and in the custody of the banks and found them to agree with the book records.

We have compared the stated income of such securities with the receipts of record and found them in agreement therewith.

We have examined all vouchers covering disbursements for account of the Institution during the fiscal year ended June 30, 1942, together with the authority therefor, and have compared them with the Institution's record of expenditures and found them to agree.

We have examined and verified the accounts of the Institution with each trust fund.

We found the books of account and records well and accurately kept and the securities conveniently filed and securely cared for.

All information requested by your auditors was promptly and courteously furnished.

We certify the Balance Sheet, in our opinion, correctly presents the financial condition of the Institution as at June 30, 1942.

Respectfully submitted.

WILLIAM L. YAEGER,
Certified Public Accountant.

Respectfully submitted.

FREDERIC A. DELANO,
VANNEVAR BUSH,
CLARENCE CANNON,
Executive Committee.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1942

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ADVERTISEMENT

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1942.

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THE 1914 TESTS OF THE LANGLEY "AERODROME"[1]

By C. G. Abbot

Secretary, Smithsonian Institution

Note.—This paper has been submitted to Dr. Orville Wright, and under date of October 8, 1942, he states that the paper as now prepared will be acceptable to him if given adequate publication.

It is everywhere acknowledged that the Wright brothers were the first to make sustained flights in a heavier-than-air machine at Kitty Hawk, North Carolina, on December 17, 1903.

Mainly because of acts and statements of former officers of the Smithsonian Institution, arising from tests made with the reconditioned Langley plane of 1903 at Hammondsport, New York, in 1914, Dr. Orville Wright feels that the Institution adopted an unfair and injurious attitude. He therefore sent the original Wright Kitty Hawk plane to England in 1928. The nature of the acts and statements referred to are as follows:

In March 1914, Secretary Walcott contracted with Glenn H. Curtiss to attempt a flight with the Langley machine. This action seems ill considered and open to criticism. For in January 1914, the United States Court of Appeals, Second Circuit, had handed down a decision recognizing the Wrights as "pioneers in the practical art of flying with heavier-than-air machines" and pronouncing Glenn H. Curtiss an infringer of their patent. Hence, in view of probable further litigation, the Wrights stood to lose in fame and revenue and Curtiss stood to gain pecuniarily, should the experiments at Hammondsport indicate that Langley's plane was capable of sustained flight in 1903, previous to the successful flights made December 17, 1903, by the Wrights at Kitty Hawk, N. C.

The machine was shipped to Curtiss at Hammondsport, N. Y., in April. Dr. Zahm, the Recorder of the Langley Aerodynamical Laboratory and expert witness for Curtiss in the patent litigation, was at Hammondsport as official representative of the Smithsonian Institu-

[1] Reprinted from Smithsonian Miscellaneous Collections, vol. 103, No. 8, Oct. 24, 1942. For an account of early Langley and Wright aeronautical investigations, see Smithsonian Report for 1900 and The Century Magazine of September 1908.

tion during the time the machine was being reconstructed and tested. In the reconstruction the machine was changed from what it was in 1903 in a number of particulars as given in Dr. Wright's list of differences which appears later in this paper. On the 28th of May and the 2d of June, 1914, attempts to fly were made. After acquiring speed by running on hydroplane floats on the surface of Lake Keuka the machine lifted into the air several different times. The longest time off the water with the Langley motor was approximately five seconds. Dr. Zahm stated that "it was apparent that owing to the great weight which had been given to the structure by adding the floats it was necessary to increase the propeller thrust". So no further attempts were made to fly with the Langley 52 HP engine.

It is to be regretted that the Institution published statements repeatedly [3] to the effect that these experiments of 1914 demonstrated that Langley's plane of 1903 without essential modification was the first heavier-than-air machine capable of maintaining sustained human flight.

As first exhibited in the United States National Museum, January 15, 1918, the restored Langley plane of 1903 bore the following label:

THE ORIGINAL, FULL-SIZE
LANGLEY FLYING MACHINE, 1903

For this simple label others were later substituted containing the claim that Langley's machine "was the first man-carrying aeroplane in the history of the world capable of sustained free flight."

Though the matter of the label is not now an issue, it seems only fair to the Institution to say that in September 1928, Secretary Abbot finally caused the label of the Langley machine to be changed to read simply as follows:

LANGLEY AERODROME

THE ORIGINAL SAMUEL PIERPONT LANGLEY
FLYING MACHINE OF 1903, RESTORED.

Deposited by
The Smithsonian Institution

301,613

This change has frequently been overlooked by writers on the controversy.

In January 1942, Mr. Fred C. Kelly, of Peninsula, Ohio, communicated to me a list of differences between the Langley plane as tested in 1914 and as tested in 1903, which he had received from Dr. Wright.

[3] Smithsonian Reports: 1914, pp. 9, 219, 221, 222; 1915, pp. 14, 121; 1917, p. 4; 1918, pp. 3, 28, 114, 166. Report of U. S. National Museum, 1914, pp. 46 and 47.

This list is given verbatim below. The Institution accepts Dr. Wright's statement as correct in point of facts. Inferences from the comparisons are primarily the province of interested experts and are not discussed here.

COMPARISON OF THE LANGLEY MACHINE OF 1903 WITH THE HAMMONDSPORT MACHINE OF MAY-JUNE, 1914

WINGS

LANGLEY, 1903	HAMMONDSPORT, 1914
1 SIZE: 11'6" x 22'6" (L. M. p. 206)	SIZE: 10'11¾" x 22'6"
2 AREA: 1040 sq. ft. (L. M. p. 206)	AREA: 988 sq. ft.
3 ASPECT RATIO: 1.98	ASPECT RATIO: 2.05
4 CAMBER: 1/12 (L. M. p. 205)	CAMBER: 1/18
5 LEADING EDGE: Wire 1/16" diameter (L. M. Pl. 66)	LEADING EDGE: Cylindrical spar 1½" dia. at inner end, tapering to 1" dia. at outer end.
6 COVERING: Cotton fabric, not varnished.	COVERING: Cotton fabric, varnished.
7 CENTER SPAR: Cylindrical wooden spar, measuring 1½" dia. for half its length and tapering to 1" at its tip. (L. M. p. 204). Located on upper side of wing.	CENTER SPAR: Cylindrical spar about 1½" dia. at inner end, tapering to about 1" dia. at outer end. Located on upper side of wing. This center spar was reinforced (1) by an extra wooden member on the under side of the wing, which measured 1" x 1½" and extended to the 7th rib from the center of the machine; and (2) by another wooden reinforcement on the under side extending out about one-fourth of the length of the wing.
9 RIBS: Hollow box construction. (L. M. Plates 66, 67)	RIBS: Most of the original Langley box ribs were replaced with others made at Hammondsport. (Manly letter, 1914). The Hammondsport ribs were of solid construction and made of laminated wood. That part of the rib in front of the forward spar was entirely omitted.

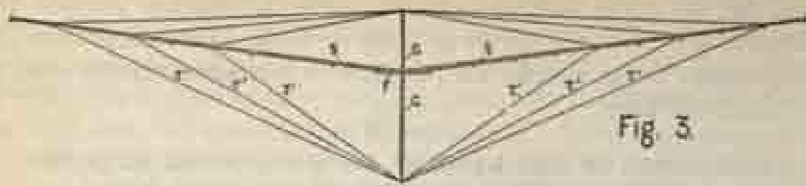

Fig. 3.

LANGLEY WING TRUSSING 1903.

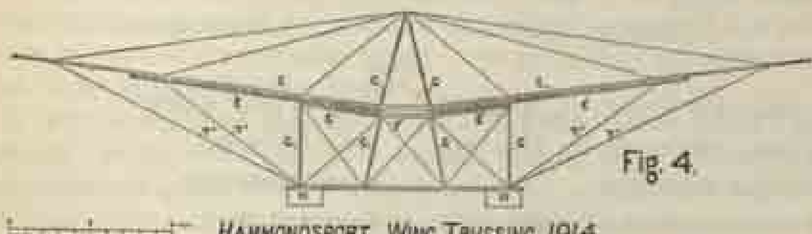

Fig. 4.

HAMMONDSPORT WING TRUSSING 1914.

9	LOWER GUY-POSTS: A single round wooden post for each pair of wings (see Fig. 3), 1¼" in dia. 6½' long. (L. M. Plate 62, p. 184).	LOWER GUY-POSTS: Four for each pair of wings (see Fig. 4), two of which were of streamline form measuring 1¼" x 3½" x 54" long; and two measuring 2" x 2" with rounded corners, 3'9" long.
10	The front wing guy-post was located 28½" in front of the main center spar. (L. M. Plate 53).	The front wing guy-posts were located directly underneath the main center spar, 28½" further rearward than in 1903.
11	The rear wing guy-post was located 31½" in front of the main center spar. (L. M. Plate 53).	The rear wing guy-posts were located directly under the main center spar, 31½" further rearward than in 1903.
12	UPPER GUY-POSTS: For each pair of wings a single steel tube ¾" dia., 43" long. (L. M. p. 184, pl. 62).	UPPER GUY-POSTS: For each pair of wings, two streamline wooden posts each 1¼" x 3½", 76" long, forming an inverted V. (See Fig. 4).
13	Front wing upper guy-post located 28½" in front of the main center spar. (L. M. pl. 53).	Front wing upper guy-posts located directly over main spar, 28½" further rearward than in 1903.
14	The rear wing upper guy-post was located 31½" in front of the main center spar. (L. M. pl. 53).	The rear wing guy-posts were located directly over the main center spar, 31½" further rearward than in 1903.
15	TRUSSING: The wing trussing wires were attached to the spars at the 5th, 7th and 9th ribs out from the center (L. M. pl. 54). The angles between these wires and the spars to which they were attached are shown in Fig. 3.	TRUSSING: A different system of wing trussing was used, and the wing trussing wires were attached to the spars at the 3rd, 6th and 9th ribs from the center. The angles between these wires and the spars to which they were attached were all different from those in the original Langley machine. (See Fig. 4).

CONTROL SURFACES

16	VANE RUDDER: A split vane composed of two surfaces united at their leading edges and separated 15'' at their trailing edges, thus forming a wedge. Each surface measured 2'3'' x 4'6'', with aspect ratio .5. (L. M. p. 214, pls. 53, 54).	VERTICAL RUDDER: The Langley vane rudder was replaced by a single plane vertical rudder which measured 3'6'' x 5', with aspect ratio of .7.
17	Operated by means of a wheel located slightly in front of the pilot at his right side and at the height of his shoulder (L. M. p. 216, pls. 53, 54).	Operated at Hammondsport through the Curtiss steering wheel in some tests, (Zahm affidavit pp. 5, 6), through the Curtiss shoulder yoke in some others (Manly letter, 1914), and fixed so as not to be operable at all in still others, (Zahm affidavit p. 7).
18	Used for steering only (L. M. p. 214).	Used "as a vertical aileron to control the lateral poise of the machine", (Zahm affidavit p. 6) as well as for steering. (Zahm affidavit p. 7).
19	PENAUD TAIL: This was a dart-shaped tail having a vertical and a horizontal surface (Penaud tail), each measuring 95 sq. ft. It was located in the rear of the main frame.	TAIL RUDDER: Same size and construction as in 1903.
20	Attached to a bracket extending below the main frame.	Attached to same bracket at a point about 8'' higher than in 1903.
21	"Normally inactive", (L. M. p. 216) but adjustable about a transverse horizontal axis by means of a self-locking wheel located at the right side of the pilot, even with his back, and at the height of his shoulder. (L. M. pls. 51, 53).	Operable about a transverse horizontal axis and connected to a regular Curtiss elevator control post directly in front of the pilot (Zahm affidavit p. 5).
22	Immovable about a vertical axis. (L. M. p. 214, pl. 56, Fig. 1.) No means were provided for adjusting this rudder about a vertical axis in flight. "Although it was necessary that the large aerodrome should be capable of being steered in a horizontal direction, it was felt to be unwise to give the Penaud tail and rudder motion in the horizontal plane in order to attain this end." (L. M. p. 214).	Immovable about a vertical axis on May 28, 1914, only. Thereafter it was made movable about a vertical axis and was connected through cables to a Curtiss steering wheel mounted on a Curtiss control post directly in front of the pilot.
23	KEEL: A fixed vertical surface underneath the main frame measuring 3'2'' in height by 6' average length. Area 19 sq. ft. (L. M. pl. 53).	KEEL: Entirely omitted.

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SYSTEM OF CONTROL

24	LATERAL STABILITY: The dihedral only was used for maintaining lateral balance. (L. M. p. 45).	LATERAL STABILITY: Three means were used for securing lateral balance at Hammondsport: The dihedral angle as used by Langley, a rudder which "serves as a vertical aileron" (Zahm affidavit p. 6), and the Penaud tail rudder. The last two constituted a system "identical in principle with that of Complainant's [Wright] combined warping of the wings and the use of the vertical rudder". (Zahm affidavit p. 6).
25	LONGITUDINAL STABILITY: Langley relied upon the Penaud system of inherent stability for maintaining the longitudinal equilibrium. "For the preservation of the equilibrium [longitudinal] of the aerodrome, though the aviator might assist by such slight movements as he was able to make in the limited space of the aviator's car, the main reliance was upon the Penaud tail." (L. M. p. 215).	LONGITUDINAL STABILITY: At Hammondsport the Penaud inherent longitudinal stability was supplemented with an elevator system of control.
26	STEERING: Steering in the horizontal plane was done entirely by the split-vane steering rudder located underneath the main frame. (L. M. p. 214).	STEERING: On one day, May 28, 1914, steering in the horizontal plane was done with the vertical rudder which had been substituted for the original Langley split-vane steering rudder. After May 28th the steering was done by the vertical surface of the tail rudder (Zahm affidavit p. 7), which in 1903 was immovable about a vertical axis. (L. M. p. 214).

POWER PLANT

27	MOTOR: Langley 5 cylinder radial.	MOTOR: Langley motor modified.
28	IGNITION: Jump spark with dry cell batteries. (L. M. p. 262).	IGNITION: Jump spark with magneto.
29	CARBURETOR: Balzer carburetor consisting of a chamber filled with lumps of porous cellular wood saturated with gasoline. The air was drawn through this wood. There was no float feed. (L. M. p. 225).	CARBURETOR: Automobile type with float feed.
30	RADIATOR: Tubes with radiating fins.	RADIATOR: Automobile radiator of honeycomb type.
31	PROPELLERS: Langley propellers (L. M. pl. 53, pp. 178–182).	PROPELLERS: Langley propellers modified "after fashion of early Wright blades".

LAUNCHING AND FLOATS

32	LAUNCHING: Catapult mounted on a houseboat.	LAUNCHING: Hydroplanes, developed 1909-1914, attached to the machine.
33	FLOATS: Five cylindrical tin floats, with conical ends, attached to underside of main frame at appropriate points, and about six feet above lowest part of machine.	FLOATS: Two wooden hydroplane floats, mounted beneath and about 6 feet to either side of the center of the machine at the lateral extremities of the Pratt system of trussing used for bracing the wing spars of the forward wings; and one (part of the time two) tin cylindrical floats with conical ends, similar to but larger than the Langley floats, mounted at the center of the Pratt system of trussing used for bracing the rear wings. All of the floats were mounted from four to five feet lower than the floats of the original Langley, thus keeping the entire machine above the water.

WEIGHT

34	TOTAL WEIGHT: With pilot, 850 pounds (L. M. p. 250).	TOTAL WEIGHT: With pilot, 1170 pounds.
35	CENTER GRAVITY: 3/8'' above line of thrust.	CENTER GRAVITY: About one foot below line of thrust.

Since I became Secretary, in 1928, I have made many efforts to compose the Smithsonian-Wright controversy, which I inherited. I will now, speaking for the Smithsonian Institution, make the following statement in an attempt to correct as far as now possible acts and assertions of former Smithsonian officials that may have been misleading or are held to be detrimental to the Wrights.

1. I sincerely regret that the Institution employed to make the tests of 1914 an agent who had been an unsuccessful defendant in patent litigation brought against him by the Wrights.

2. I sincerely regret that statements were repeatedly made by officers of the Institution that the Langley machine was flown in 1914 "with certain changes of the machine necessary to use pontoons," without mentioning the other changes included in Dr. Wright's list.

3. I point out that Assistant Secretary Rathbun was misinformed when he stated that the Langley machine "without modification" made "successful flights."

4. I sincerely regret the public statement by officers of the Institution that "The tests" [of 1914] showed "that the late Secretary Langley had succeeded in building the first aeroplane capable of sustained free flight with a man."

5. Leaving to experts to formulate the conclusions arising from the 1914 tests as a whole, in view of all the facts, I repeat in substance, but with amendments, what I have already published in Smithsonian Scientific Series, Vol. 12, 1932, page 227:

> The flights of the Langley aerodrome at Hammondsport in 1914, having been made long after flying had become a common art, and with changes of the machine indicated by Dr. Wright's comparison as given above, did not warrant the statements published by the Smithsonian Institution that these tests proved that the large Langley machine of 1903 was capable of sustained flight carrying a man.

6. If the publication of this paper should clear the way for Dr. Wright to bring back to America the Kitty Hawk machine to which all the world awards first place, it will be a source of profound and enduring gratification to his countrymen everywhere. Should he decide to deposit the plane in the United States National Museum, it would be given the highest place of honor, which is its due.

THE PROBLEM OF THE EXPANDING UNIVERSE[1]

By Edwin Hubble
Mount Wilson Observatory

I propose to discuss the problem of the expanding universe from the observational point of view. The fact that such a venture is permissible is emphatic evidence that empirical research has definitely entered the field of cosmology. The exploration of space has swept outward in successive waves, first, through the system of the planets, then, through the stellar system, and, finally, into the realm of the nebulae. Today we study a region of space so vast and so homogeneous that it may well be a fair sample of the universe. At any rate, we are justified in adopting the assumption as a working hypothesis and attempting to infer the nature of the universe from the observed characteristics of the sample. One phase of this ambitious project is the observational test of the current theory of the expanding universes of general relativity.

I shall briefly describe the observable region of space as revealed by preliminary reconnaissance with large telescopes, then sketch the theory in outline, and, finally, discuss the recent more accurate observations that were designed to clarify and to test the theory.

THE OBSERVABLE REGION

The sun, as you know, is a star, one of several thousand million stars which together form the stellar system. This system is a great swarm of stars isolated in space. It drifts through the universe as a swarm of bees moves through the summer air. From our position near the sun we look out through the swarm of stars, past the borders, and into the universe beyond.

Until recently those outer regions lay in the realm of speculation. Today we explore them with confidence. They are empty for the most part, vast stretches of empty space. But here and there, separated by immense intervals, other stellar systems are found, comparable with our own. We find them thinly scattered through space

[1] Reprinted by permission from the Sigma Xi quarterly, vol. 30, No. 2, April 1942. Included in Science in Progress, Series III, fall, 1942.

out as far as telescopes can reach. They are so distant that, in general, they appear as small faint clouds mingled among the stars, and many of them have long been known by the name "nebulae." Their identification as great stellar systems, the true inhabitants of the universe, was a recent achievement of great telescopes.

On photographs made with such instruments, these nebulae, these stellar systems, appear in many forms. Nevertheless they fall naturally into an ordered sequence ranging from compact globular masses through flattening ellipsoids into a line of unwinding spirals. The array exhibits the progressive development of a single basic pattern, and is known as the sequence of classification. It may represent the life history of stellar systems. At any rate, it emphasizes the common features of bodies that belong to a single family.

Consistent with this interpretation is the fact that these stellar systems, regardless of their structural forms, are all of the same general order of intrinsic luminosity; that is, of candlepower. They average about 100 million suns and most of them fall within the narrow range from one-half to twice this average value. Giants and dwarfs are known, 10 to 20 times brighter or fainter than the average, but their numbers appear to be relatively small. This conclusion is definitely established in the case of giants, which can be readily observed throughout an immense volume of space, but is still speculative in the case of dwarfs which can be studied only in our immediate vicinity.

The limited range in luminosity is important because it offers a convenient measure of distance. As a first approximation, we may assume that the nebulae are all equally luminous, and, consequently, that their apparent faintness indicates their distances. The procedure is not reliable in the case of a single object because the particular nebula might happen to be a giant or a dwarf rather than a normal stellar system. But for statistical purposes, where large numbers of nebulae are involved, the relatively few giants and dwarfs should average out, and the mean distances of large groups may be accurately determined. It is by this method that the more remote regions of space, near the limits of the telescope, may be explored with confidence.

Throughout the observable region the nebulae are found scattered singly, in pairs, and in groups up to great compact clusters or even clouds. The small-scale distribution is irregular, and is dominated by a tendency toward clustering. Yet when larger and larger volumes of space are compared, the minor irregularities tend to average out, and the samples grow more and more uniform. If the observable region were divided into a hundred or even a thousand equal parts, the contents would probably be nearly identical. Therefore, the large-scale distribution of nebulae is said to be uniform; the observable re-

gion is homogeneous, very much the same everywhere and in all directions.

We may now present a rough sketch of our sample of the universe. The faintest nebulae that can be detected with the largest telescope in operation (the 100-inch reflector on Mount Wilson) are about 2 million times fainter than the faintest star that can be seen with the naked eye. Since we know the average candlepower of these nebulae, we can estimate their average distance—500 million light-years. A sphere with this radius defines the observable region of space. Throughout the sphere are scattered about 100 million nebulae, at various stages of their evolutional development. These nebulae average about 100 million times brighter than the sun and several thousand million times more massive. Our own stellar system is a giant nebula, and is presumably a well-developed, open spiral. The nebulae are found, as has been said, singly, in groups and in clusters but, on the grand scale, these local irregularities average out and the observable region as a whole is approximately homogeneous. The average interval between neighboring nebulae is about 2 million light-years, and the internebular space is sensibly transparent.

THE LAW OF RED SHIFTS

Another general characteristic of the observable region has been found in the law of red shifts, sometimes called the velocity-distance relation. This feature introduces the subject of spectrum analysis. It is well known that, in general, light from any source is a composite of many individual colors or wave lengths. When the composite beam passes through a glass prism or other suitable device, the individual colors are separated out in an ordered rainbow sequence, known as a spectrum. The prism bends the light waves according to the wave length. The deflections are least for the long waves of the red and are greatest for the short waves of the violet. Hence position in the spectrum indicates the wave length of the light falling at any particular place in the sequence.

Incandescent solids, and certain other sources, radiate light of all possible wave lengths, and their spectra are continuous. Incandescent gases, however, radiate only certain particular wave lengths, and their spectra, called emission spectra, consist of various isolated colors separated by blank spaces. The patterns are well known, hence gases in a distant light source can be identified by their spectra.

The sun presents a third kind of spectrum, known as an absorption spectrum. The main body of the sun furnishes a continuous spectrum. The heavy atmosphere surrounding the main body is gaseous and would normally exhibit an emission spectrum. Actually, the atmosphere, because it is cooler than the main body, absorbs from the

continuous background those colors it would otherwise emit. Therefore the solar spectrum is a continuous spectrum on which is superposed a pattern of dark gaps or lines. These dark lines identify the gases in the solar atmosphere and indicate the physical conditions under which they exist.

The nebulae are stellar systems, and their spectra resemble that of the sun. Dark lines due to calcium, hydrogen, iron, and other elements in the atmospheres of the component stars are identified with complete confidence. In the case of the nearer nebulae, these lines are close to their normal positions as determined in the laboratory or in the sun. In general, however, accurate measures disclose slight displacements, either to the red or to the violet side of the exact normal positions.

Such small displacements are familiar features in the spectra of stars and are known to be introduced by rapid motion in the line of sight. If a star is rapidly approaching the observer, the light waves are crowded together and shortened, and all the spectral lines appear slightly to the violet side of the normal positions. Conversely, rapid recession of a star drags out and lengthens the light waves, and the spectral lines are seen to the red of their normal positions.

The amounts of these displacements (they are called Doppler shifts) indicate the velocities of the stars in the line of sight. If the wave lengths are altered by a certain fraction of the normal wave lengths, the star is moving at a velocity which is that same fraction of the velocity of light. In this way it has been found that the stars are drifting about at average speeds of 10 to 30 miles per second, and, indeed, that the stellar system, our own nebula, is rotating about its center at the majestic rate of one revolution in perhaps 200 million years.

Similarly, the nebulae are found to be drifting about in space at average speeds of the order of 150 miles per second. Such speeds, of course, are minute fractions of the velocity of light, and the corresponding Doppler shifts, which may be either to the violet or to the red, are barely perceptible.

But the spectra of distant nebulae show another effect as conspicuous as it is remarkable. The dark absorption lines are found far to the red of their normal positions. Superposed on the small red or violet shifts representing individual motions, is a systematic shift to the red which increases directly with the distances of the nebulae observed. If one nebula is twice as far away as another, the red shift will be twice as large; if *n* times as far away, the red shift will be *n* times as large. This relation is known as the law of red shifts; it appears to be quite a general feature of the observable region of space.

If these systematic red shifts are interpreted as the familiar Doppler shifts, it follows that the nebulae are receding from us in all directions at velocities that increase directly with the momentary distances. The rate of increase is about 100 miles per second per million light-years of distance, and the observations have been carried out to nearly 250 million light-years where the red shifts correspond to velocities of recession of nearly 25,000 miles per second or ⅐ the velocity of light.

On this interpretation the present distribution of nebulae could be accounted for by the assumption that all the nebulae were once jammed together in a very small volume of space. Then, at a certain instant, some 1,800 million years ago, the jam exploded, the nebulae rushed outward in all directions with all possible velocities, and they have maintained these velocities to the present day. Thus the nebulae have now receded to various distances, depending upon their initial velocities, and our observations necessarily uncover the law of red shifts.

This pattern of history seems so remarkable that some observers view it with pardonable reserve, and try to imagine alternative explanations for the law of red shifts. Up to the present, they have failed. Other ways are known by which red shifts might be produced, but all of them introduce additional effects that should be conspicuous and actually are not found. Red shifts represent Doppler effects, physical recession of the nebulae, or the action of some hitherto unrecognized principle in nature.

COSMOLOGICAL THEORY

The preliminary sketch of the observable region was completed about 10 years ago. It was not necessarily a finished picture, but it furnished a rough framework within which precise, detailed investigations could be planned with a proper understanding of their relation to the general scheme. Such new investigations, of course, were guided when practical by current theory. Let me explain the significance of this procedure.

Mathematicians deal with possible worlds, with an infinite number of logically consistent systems. Observers explore the one particular world we inhabit. Between the two stands the theorist. He studies possible worlds but only those which are compatible with the information furnished by observers. In other words, theory attempts to segregate the minimum number of possible worlds which must include the actual world we inhabit. Then the observer, with new factual information, attempts to reduce the list still further. And so it goes, observation and theory advancing together toward the common goal of science, knowledge of the structure and behavior of the physical universe.

The relation is evident in the history of cosmology. The study at first was pure speculation. But the exploration of space moved outward until finally a vast region, possibly a fair sample of the universe, was opened for inspection. Then theory was revitalized; it now had a sure base from which to venture forth.

Current theory starts with two fundamental principles: general relativity and the cosmological principle. General relativity states that the geometry of space is determined by the contents of space, and formulates the nature of the relation. Crudely put, the principle states that space is curved in the vicinity of matter, and that the amount of curvature depends upon the amount of matter. Because of the irregular distribution of matter in our world, the small-scale structure of space is highly complex. However, if the universe is sufficiently homogeneous on the large scale, we may adopt a general curvature for the universe, or for the observable region as a whole, just as we speak of the general curvature of the earth's surface, disregarding the mountains and ocean basins. The nature of the spatial curvature, whether it is positive or negative, and the numerical value, is a subject for empirical investigation.

The second, or cosmological principle is a pure assumption—the very simple postulate that, on the grand scale, the universe will appear much the same from whatever position it may be explored. In other words, there is no favored position in the universe, no center, no boundaries. If we, on the earth, see the universe expanding in all directions, then any other observer, no matter where he is located, will also see the universe expanding in the same manner. The postulate, it may be added, implies that, on the grand scale, the universe is homogeneous and isotropic—very much the same everywhere and in all directions.

Modern cosmological theory attempts to describe the types of universes that are compatible with the two principles, general relativity and the cosmological principle. Profound analysis of the problem leads to the following conclusions. Such universes are unstable. They might be momentarily in equilibrium, but the slightest internal disturbance would destroy the balance, and disturbances must occur. Therefore, these possible worlds are not stationary. They are, in general, either contracting or expanding, although theory in its present form does not indicate either the direction of change or the rate of change. At this point, the theorist turned to the reports of the observers. The empirical law of red shifts was accepted as visible evidence that the universe is expanding in a particular manner and at a known rate. Thus arose the conception of homogeneous expanding universe of general relativity.

In such universes, the spatial curvature is steadily diminishing as the expansion progresses. Furthermore, the nature of the expansion

is such that gravitational assemblages maintain their identities. In other words, material bodies or groups and clusters of nebulae do not themselves expand but maintain their permanent dimensions as their neighbors recede from them in all directions.

Several types of expanding universes are possible, and some of them can be further specified by the nature of the curvature, whether it is positive or negative. In fact, the particular universe we inhabit could be identified if we had sufficiently precise information on three measurable quantities, namely, the rate of expansion, the mean density of matter in space, and the spatial curvature at the present epoch. Recent empirical investigations have been directed toward these problems, and the results will be briefly described in the remaining section of this discussion.

COMPARISON OF THEORY AND OBSERVATIONS

We may begin with two results which are thoroughly consistent with the theory. The first result concerns the assumption of homogeneity; the second, the conclusion that groups maintain their dimensions as the universe expands.

The distribution of nebulae has been studied in two ways. The first information came from sampling surveys at Mount Wilson and at the Lick Observatory. Small areas, systematically scattered over the sky, were studied with large telescopes. Thus the nebulae that were counted lay in narrow cones penetrating to vast distances. These surveys established large-scale homogeneity over the three-quarters of the sky that could be studied from the northern latitudes of the observatories involved.

Later, the Harvard College Observatory, with the help of its southern station, has furnished counts of the nebulae extending over large areas but made with moderate-size telescopes. In other words, these nebulae are scattered through wide cones penetrating to moderate distances. Shapley, in his reports, has stressed or perhaps overstressed, the familiar, small-scale irregularities of distribution, but analysis of such published data as are adequately calibrated agrees with the earlier conclusion. In fact, the mean results from the two quite different methods of study are sensibly the same. This fact reemphasizes the large-scale homogeneity of the observable region.

The second result is derived from a study of the Local Group. Our own stellar system is one of a dozen nebulae that form a loose group, more or less isolated in the general field. These neighboring systems furnished the first clues to the nature of the nebulae and the scale of internebular distances. They are so near that their brightest stars could be recognized and compared with similar stars in our own system. Radial velocities of the members of the Local Group, listed in

table 1, suggest that the law of red shifts probably does not operate within the group. This conclusion is positive evidence supporting the validity of the theory. If the universe is expanding, the group maintains its dimensions as the theory requires.

The remainder of the recently accumulated information is not favorable to the theory. It is so damaging, in fact, that the theory, in its present form, can be saved only by assuming that the observational results include hidden systematic errors. The latter possibility will naturally persist until the investigations can be repeated and improved. Nevertheless, a careful reexamination of the data now available suggests no adequate explanation of the discrepancies.

TABLE 2.—*Radial velocities in the Local Group*

The observed velocities (second column) represent a more reasonable distribution than the velocities corrected for red shifts (fifth column). The latter are all large and negative with the exception of the first two, for which the red shifts are insignificant. This fact suggests that the law of red shifts does not operate within the Local Group.

LOCAL GROUP

Known members	Observed velocity	Distance in million light-years	Expected red shift	Velocity with red shift removed
L M C	+ 45	0.085	+ 13	+ 32
S M C	+ 13	0.085	+ 16	− 3
M 31	−130	0.7	+110	−240
M 33	−150	0.7	+110	−260
NGC 6822	+ 20	0.5	+ 85	− 60
IC 1613*	—	1.3	+210	—
Fornax	− 40	0.6	+100	−140
Probable members				
NGC 6946	+ 90	1.6	+265	−175
NGC 1569	+ 60	2.3	+370	−310
IC 342	+ 30	2.3	+370	−340

*A spectrum of an object in IC 1613, obtained by Baade, shows a definitely negative velocity. The numerical value of the velocity is rather uncertain, and, for this reason is not included in the table. However, the negative sign indicates that IC 1613 is consistent with the other members of the Local Group.

THE INTERPRETATION OF RED SHIFTS

The investigations were designed to determine whether or not red shifts represent actual recession. In principle, the problem can be solved; a rapidly receding light source appears fainter than a similar but stationary source at the same momentary distance. The explanation of this well-known effect is quite simple when the beam of light is pictured as a stream of discrete quanta. Rapid recession thins out the stream of quanta, hence fewer quanta reach the eye per second, and the intensity, or rate of impact, is necessarily re-

duced. Quantitatively, the normal brightness is reduced by a fraction that is merely the velocity of recession divided by the velocity of light—in other words, the red shift expressed as a fraction of the normal wave lengths of the light in question. Recession at one-tenth the velocity of light reduces the apparent brightness by 10 percent; at one-quarter the velocity of light, by 25 percent.

For velocities of a few miles or a few hundred miles per second, the dimming factor is negligible. But for the extremely distant nebulae, where the apparent recessions reach tens of thousands of miles per second, the effects are large enough to be readily observed and measured. Hence, if the distances of nebulae were known quite accurately we could measure their apparent faintness and tell at once whether or not they are receding at the rates indicated by the red shifts.

Unfortunately, the problem is not so simple. The only general criterion of great distance is the very apparent faintness of the nebulae which we wish to test. Therefore, the proposed test involves a vicious circle, and the dimming factor merely leads to an error in distance. However, a possible escape from the vicious circle is found in the following procedure. Since the intrinsic luminosities of nebulae are known, their apparent faintness furnishes two scales of distances, depending upon whether we assume the nebulae to be stationary or receding. If, then, we analyze our data, if we map the observable region, using first one scale and then the other, we may find that the wrong scale leads to contradictions or at least to grave difficulties. Such attempts have been made and one scale does lead to trouble. It is the scale which includes the dimming factors of recession, which assumes that the universe is expanding.

ALTERNATIVE FORMS OF THE LAW OF RED SHIFTS

The project was carried out by the precise formulation of (a) the law of red shifts, and (b) the large-scale distribution of nebulae. The form of the law of red shifts is most readily derived from the study of the brightest nebulae in the great clusters. These nebulae, as a class, are the most luminous bodies in the universe, and their spectra can be recorded out to the maximum distances. Furthermore, the clusters are so similar that the apparent faintness of the 5 or 10 brightest members furnish reliable relative distances. The observations now extend out to about 240 million light-years where the red shift is about 13 percent of the normal wave lengths of the incoming light. Since the corresponding velocity of recession is the same fraction of the velocity of light, the nebulae in the most distant cluster observed, if they are actually receding, will appear 13 percent fainter than they would appear if they were stationary. The dif-

ference is small but, fortunately, the measures can be made with fair accuracy.

The results may be stated simply. If the nebulae are stationary, the law of red shifts is sensibly linear; red shifts are a constant multiple of distances. In other words, each unit of light path contributes the same amount of red shift.

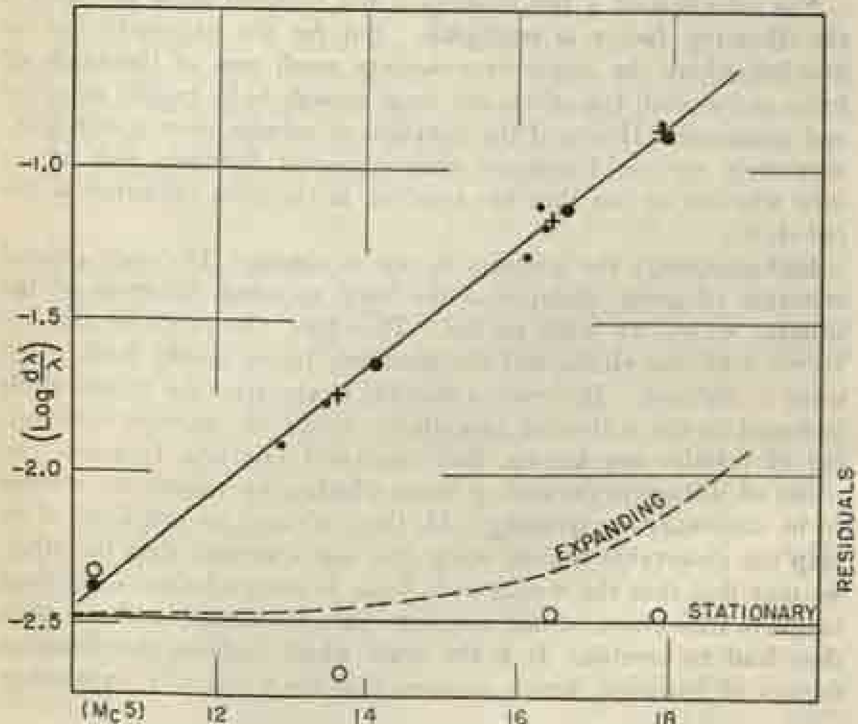

FIGURE 1.—The law of red shifts. The law of red shifts at very great distances is derived as a relation between apparent magnitudes of the fifth brightest members of clusters and the mean red shifts observed in the clusters. The relation, log $d\lambda/\lambda$ = 0.2 m_5 + constant, shown as a full line in the diagram, indicates a linear law of red shifts ($d\lambda/\lambda$=constant × distance).

In the diagram, large disks represent clusters of high weight; dots, clusters of low weight; crosses, weighted means. Observed magnitudes have been corrected for all known effects (including the "energy effects," $3d\lambda/\lambda$), except recession factors. Thus, for a stationary universe, the law of red shifts is sensibly linear.

For an expanding universe, the recession factors would be applied, and the law would depart from the linear form. Such departures, shown by the broken curve, imply that the rate of expansion has been slowing down, and that the "age of the universe," the time since the expansion started, is less than 1,000 million years.

The diagram includes minor revisions of the observational data in accordance with recent investigations.

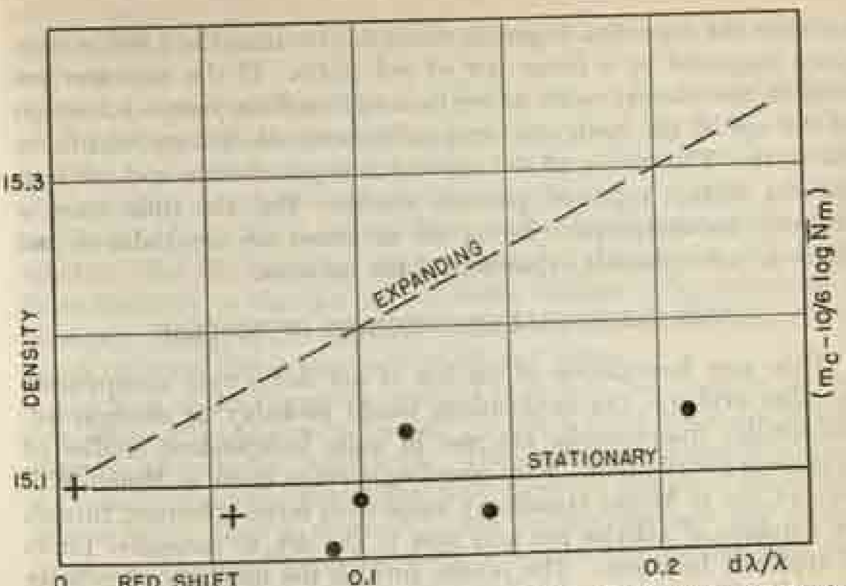

FIGURE 2—Large-scale distribution of nebulae. If N_m is the number of nebulae per square degree brighter than apparent magnitude m, then the average density (number of nebulae divided by volume of space), in arbitrary units, is represented by (log N_m—0.6m). Each point in the diagram represents a survey in which the observed m have been corrected for all known effects (including the "energy effects," 3 dλ/λ) but omitting the "recession factors," dλ/λ. The diagram indicates that for a stationary universe, the density is independent of distance (or red shift).

If the universe were expanding, "recession factors" should be applied, and the points would fall along the broken line, indicating that the density increases steadily with distance. In order to escape this conclusion, it is necessary to introduce still another effect such as spatial curvature which exactly compensates the recession factors.

The dots represent surveys made at Mount Wilson and Mount Hamilton; the first cross, the Shapley-Ames survey to m=13±; the second cross, Harvard counts to m=17.5, extracted from Proc. Nat. Acad. Sci., vol. 24, p. 148, 1938, and vol. 26, pp. 166 and 554, 1940, and reduced according to the procedure used in reducing the deeper surveys.

On the other hand, if the nebulae are receding, and the dimming factors are applied, the scale of distances is altered, and the law of red shifts is no longer linear. The rate of expansion increases more and more rapidly with distance. The significance of this result becomes clear when the picture is reversed. Light that reaches us today left the distant nebulae far back in the dim past—hundreds of millions of years ago. When we say that the rate of expansion increases with distance, we are saying that long ago, the universe was expanding much faster than it is today; that, for the last several hundred million years at least, the rate of expansion has been slowing down. Therefore, the so-called "age of the universe," the time inter-

val since the expansion began, is much shorter than the 1,800 million years suggested by a linear law of red shifts. If the measures are reliable, the interval would be less than 1,000 million years—a fraction of the age of the earth and comparable with the history of life on the earth. The nature of the expansion is permissible and, in fact, specifies certain types of possible worlds. But the time scale is probably not acceptable. Either the measures are unreliable or red shifts do not represent expansion of the universe.

THE LARGE-SCALE DISTRIBUTION OF NEBULAE

If the new formulation of the law of red shifts were unsupported by other evidence, the implications would probably be disregarded. But similar discrepancies are met in quite independent studies of large-scale distribution. Five sampling surveys (four at Mount Wilson and one at Mount Hamilton) made with large reflectors, furnish the numbers of nebulae per unit area in the sky, to successive limits of apparent faintness. The results furnish the numbers of nebulae per unit volume in five spheres whose radii range from about 155 to 420 million light-years on the stationary distance scale, or about 145 to 365 million light-years for the expanding distance scale.

On the assumption that red shifts do not represent actual recession, the large-scale distribution is sensibly homogeneous—the average number of nebulae per unit volume of space is much the same for each of the spheres. Further confirmation is found in some of the recent Harvard counts of nebulae which fall within the area of the sky covered by the deep surveys, and which are based on the same scale of apparent faintness. Sufficient data can be extracted from the reports to determine a mean density over large areas extending out to perhaps 100 million light-years, and the result is in substantial agreement with those of the earlier investigations. All of these data lead to the very simple conception of a sensibly infinite, homogeneous universe of which the observable region is an insignificant sample.

The inclusion of dimming corrections for recession, because they alter the scale of distance in a nonlinear way, necessarily destroys the homogeneity. The number of nebulae per unit volume now appears to increase systematically with distance in all directions. The result violates the cosmological principle of no favored position and, consequently, is referred to some neglected factor in the calculations. If the density appeared to diminish outward, we would at once suspect the presence of internebular obscuration, or, perhaps, the existence of a supersystem of nebulae. But an apparently increasing density offers a much more serious problem. About the only known, permissible interpretation is found in positive spatial curvature, which, by a sort of optical foreshortening, would crowd the observed nebulae into

apparently smaller and smaller volumes of space as the distance increased.

Spatial curvature is an expected feature of an expanding universe, and, together with the precise form of the law of red shifts, further specifies a particular type of possible world. Thus, if the measures were reliable, we might conclude that the initial cosmological problem had been solved; that now we knew the nature of the universe we inhabit. But the situation is not so simple. Just as the departures from linearity in the law of red shifts indicate a universe that is strangely young, so the apparent departures from homogeneity indicate a universe that is strangely small and dense.

The sign of the curvature required to restore homogeneity is positive, hence the universe is "closed"; it has a finite volume although, of course, there are no boundaries. The amount of curvature indicates the volume of the universe: about four times the volume of the observable region. Such a universe would contain perhaps 400 million nebulae. The total mass, however, would be far greater than that which can be attributed to the nebulae alone.

CONCLUSION

Thus the use of dimming corrections leads to a particular kind of universe, but one which most students are likely to reject as highly improbable. Furthermore, the strange features of this universe are merely the dimming corrections expressed in different terms. Omit the dimming factors, and the oddities vanish. We are left with the simple, even familiar, concept of a sensibly infinite universe. All the difficulties are transferred to the interpretation of red shifts which cannot then be the familiar velocity shifts.

Two further points may be mentioned. In the first place, the reference of red shifts to some hitherto unknown principle does not in any way destroy the validity of the theory of expanding universes. It merely removes the theory from immediate contact with observations. We may still suppose that the universe is either expanding or contracting, but at a rate so slow that it cannot now be disentangled from the gross effects of the superposed red shifts.

Secondly, the conclusions drawn from the empirical investigations involve the assumptions that the measures are reliable and the data are representative. These questions have been carefully reexamined during the past few years. Various minor revisions have been made, but the end results remain substantially unchanged. By the usual criteria of probable errors, the data seem to be sufficiently consistent for their purpose. Nevertheless, the operations are delicate, and the most significant data are found near the limits of the greatest tele-

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scopes. Under such conditions, it is always possible that the results may be affected by hidden systematic errors. Although no suggestion of such errors has been found, the possibility will persist until the investigations can be repeated with improved techniques and more powerful telescopes. Ultimately, the problem should be settled beyond question by the 200-inch reflector destined for Palomar. The range of that telescope, and the corresponding ranges of the dimming corrections, should be about twice those examined in the present investigations. Factors of 25 percent in the apparent brightness of nebulae at the limits of the spectrograph, and 40 to 50 percent at the limits of direct photography should be unmistakable if they really exist.

Meanwhile, on the basis of the evidence now available, apparent discrepancies between theory and observation must be recognized. A choice is presented, as once before in the days of Copernicus, between a strangely small, finite universe and a sensibly infinite universe plus a new principle of nature.

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GALAXIES[1]

By Harlow Shapley
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[With 2 plates]

Like the galaxies themselves, the field of inquiry concerning galaxies is large and not easily surveyed in a brief article. It will be well to restrict the assignment and write only concerning a few selected topics.

Let us first try a bird's-eye view of our own galaxy. The bird whose eye we would use needs to be a remarkable creature to reach the remoteness necessary for an outside look. We cannot use Cygnus the Swan, that heads in full flight along the northern Milky Way, nor Aquila the Eagle, nor the big-billed Toucan, the Flamingo, the Phoenix, the Goose, the Bird of Paradise, nor Corvus the Crow. All these constellation birds are composed of stars that are bright neighbors of the sun and distinctly localized far inside our own galaxy.

What we need is an observation point something like a million light-years distant, well outside the bounds of the enormous Milky Way system. It would be pretty satisfactory to settle our bird comfortably in the outer haze of stars of the Andromeda nebula. If the observer be a contemporary of ours, he will be looking at our system in terms of 8,000 centuries ago. It has been that long since the radiation left the sun and its neighboring stars on its way to the retina of the all-comprehending but quite imaginary bird now surveying us from the Andromeda galaxy.

Such a temporal disparity, 8×10^5 years, is of no particular moment in our considerations of the galaxies; and short-term enterprises like the current western civilization, or even the whole history of mankind, can be neglected in the cosmic panorama as too momentary, too fleeting, for a clear recording.

It is well known that the Milky Way star system is a much flattened organization and that the sun and planets are well inside.

[1] Reprinted by permission from the Sigma Xi Quarterly, vol. 30, No. 1, January 1942. Included in Science in Progress, Series III, fall, 1942.

This interpretation of the Milky Way was pointed out 190 years ago by Thomas Wright, a pioneer "bird's-eye viewer" of Durham, England. He saw that the hypothesis of a flattened stellar system with the earth near the central plane would satisfactorily explain the Milky Way band as a phenomenon of projection in such a system.[3] Our hypothetical observer in Andromeda would see this flattened wheel-shaped system not from the direction of its rim, nor from the direction of its axis, but from an intermediate position, galactic latitude −21°. It would appear in projection, therefore, as an elongated object, perhaps with the axes of the rough ellipse in the ratio of about three to one. There would be a conspicuous globular nucleus of naked-eye brightness.

We are almost certain now that our galaxy is a great openwork spiral system of stars, perhaps not much unlike the system Messier 83, shown in plate 1. But in linear measure it may be much larger than Messier 83. It has taken a long time to get conclusive evidence on the structure of our own system. We are badly located. There are obvious difficulties with residing inside. The meadow violet, no matter how bold and sensitive, is at a disadvantage in meadow topography compared with the bird hovering above.

For more than a hundred years astronomers have struggled with the problems of the structure of the galaxy. There have been many speculators, but also some hard and systematic observers. Sir William Herschel dominated this field throughout the early part of the nineteenth century. His surveys of star clusters and nebulae, his measures of brightness and positions of various celestial objects, his interpretations of the accumulating material were so important that he is appropriately considered the founder of sidereal astronomy. Before him the emphasis was on comets and planets and the positions and motions of nearby stars and the laws governing these motions. It was essentially solar-system astronomy that attracted the telescopes and the wisdom of scientists until this German-Anglican organist of Bath devised some instruments; then astronomy turned outward to interstellar spaces.

Sir William Herschel was considerably baffled by the problem of the structure of the galaxy and by the relation of clusters and nebulae to the Milky Way. His successors made many notable contributions, photometric and spectroscopic, to knowledge of the nature of stars and nebulae, but still the large cosmic problems remained baffling. Increasing telescopic strength, however, and the accumulation of many kinds and types of observations, eventaully led to less puzzlement about

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[3] For an account of the early cosmic interpretations by Thomas Wright and Immanuel Kant, see the highly interesting report by F. A. Paneth, The Observatory, pp. 71ff., June 1941; also H. Shapley, Immanuel Kant, 1724–1924, chap. 5, Yale Univ. Press, 1925, E. C. Wilm, ed.

the stellar neighbors of the sun and the nearer parts of the Milky Way. The old but unproved concept that the spiral nebulae and their relatives were external galaxies, coordinate with our own Milkey Way system, gradually became established. The dimensions of the galaxy and of the universe approached clarification, chiefly through the power of the telescopes of American observatories and the vision of European and American theoreticians.

In clarifying some of the earlier puzzles, however, the astronomers only succeeded in opening vaster vistas for exploration, interpretation, and wonderment. The net gain has been considerable. It is no longer believed that the severe difficulties of certain astronomical enterprises have definitely blocked the progress of inquiry. A hundred years ago a distinguished scientist (not an astronomer) gloated a bit over the pronouncement that one thing would certainly forever remain unknown, namely, the chemical nature of the stars! It was not many years before the spectroscope began to betray him. And at the time of her death in 1941 Dr. Annie Cannon had classified more than half a million stars on the basis of the chemistry of their surfaces. A great deal is now known of the chemical constitution of a galaxy of a billion stars at a distance of 10 million light-years. An elementary astronomical student can quickly learn, with the use of modern equipment, about the hydrogen, calcium, iron, magnesium, helium, carbon, and the like in stars that have never actually been seen except through use of the photographic plate.

The moral of that bad ancient pronouncement about stellar chemistry is that it is not wise to be discouraged with the difficulties arising from our awkward location in the galaxy. Eventually all the answers to all the questions you could now ask about Milky Way structure may be known. And, of course, we would then be wise enough to ask other questions that you could not answer, nor could we. Here are some of the current questions, and, for some of them, preliminary answers.

1. Are the sun and its planets in the middle of our discoidal galaxy? They certainly are not. There are many lines of evidence which indicate that the center is far away in the direction of the region where the constellations of Sagittarius, Ophiuchus, and Scorpio come together, 30 degrees or a little more south of the celestial equator in the thick of the bright star clouds along the Milky Way. My early study of the globular star clusters (a reproduction of an important one, 47 Tucanae, is shown in pl. 2) was instrumental in showing the observer that he is well out toward the rim of the wheel-shaped galaxy. There may be some "subcenters" in other parts of the Milky Way, in far south Carina, for instance, and in Cygnus. But those conglomerations of stars appear to be important local structures within the great galaxy that has its massive nucleus in the Sagittarius direction.

2. Is this galaxy in motion as a unit? How it moves with respect to nearby galaxies is not yet very clear, but certainly it rotates around the Sagittarius nucleus. It does not rotate as a solid wheel, at least at our distance from the nucleus. It rotates more as the planetary system rotates; the planets nearer the sun go more rapidly and complete their "years" in shorter times than the remoter planets. We think we can very definitely measure the differential speed of stars around the nucleus. The average speed in the sun's neighborhood is about 200 miles a second, and the direction of motion is toward the northern constellation of Cygnus.

3. How far are the sun and the neighboring stars from the axis of rotation? Ten kiloparsecs is the approximate answer and, since a parsec is 3.26 light-years or about 20 trillion miles, the distance is something like 2×10^{17} miles, or 30-odd thousand light-years. For various reasons, that value of 10 kiloparsecs is not too certain, but it is well established that the center of gravity of our system is between 8 and 12 kiloparsecs distant. The direction to the center is fixed with an uncertainty of only 2 or 3 degrees; this angular parameter is much easier to handle than the distance.

4. How large is the Milky Way system and how populous? Enormous in size and population, if nonquantitative terms may be used. There is good evidence that the total population in stars is of the order of 200,000 million, but the evidence on over-all dimensions is as yet inconclusive. Indeed it is somewhat involved with definitions. For instance, how define the boundary of a galaxy? Is it at the distance of the farthermost discoverable member of the system? Or is it the distance to the place where the number of stars per cubic light-year has decreased to a specified small quantity? Or is it, for a spiral galaxy, the distance to which a spiral arm can be traced? Or is it the distance to which an escaping star can go before the gravitational holdback is exceeded by the pull from some other galaxy?

The diameter of the system in its plane is not less than 100,000 light-years if all its recognizable stars are included. There is now good evidence that the wheel-shaped system is surrounded by a more or less spherical haze of stars, and some of the stars in the haze are 50,000 light-years above the plane of the Milky Way. Probably this haze extends more distantly in the plane of the system and, therefore, the diameter of discoid plus haze considerably exceeds 100,000 light-years.

On the other hand, the diameter of our system in its plane might be measured as only 50,000 light-years, or even less, if we had to depend on photographic research equipment which, although comparable with our own, was located in the Virgo supergalaxy, several million light-years away. Our outer stars might not register. When our telescopes are turned on the members of that group in Virgo we can trace

on the best of our long-exposure plates the largest individual galaxies only to a distance of 10 or 15 thousand light-years from their centers. Either those systems are very much smaller than ours, or we are unable to explore the faint regions that are as remote from the nuclei as we are from our nucleus in Sagittarius.

It might turn out, therefore, that the bird's-eye observer from the Andromeda nebula would report that our galactic system is no larger than the Andromeda nebula; or, if the research were rather casual, the view might include only the nuclear portions of our galactic system, which might even be cataloged as a spheroidal galaxy. When we, in our turn, take a quick bird's-eye view of the Andromeda galaxy, and measure its distance and dimensions, we immediately conclude that it is much smaller than we are, even though it is a giant compared with the average galaxy of our catalogs. But when the over-all extent of the Andromeda galaxy is studied with precise measuring apparatus, we double the dimensions as first seen and conclude that it is not very much smaller than the Milky Way system.

5. Why is it that we seem to be so baffled about the structure and dimensions of our own system, although we bravely go out to distances of 100 million light-years in our explorations of other galaxies? What is so troublesome about measuring something that completely surrounds us and is near at hand?

That question finally brings out one feature of Milky Way structure which must be clearly seen at first glance by the observer in Andromeda, but which has taken us many years and much labor to discover and partially evaluate. This basic feature (and difficulty) is the presence throughout the Milky Way, especially near the Milky Way plane, of interstellar absorbing material—dust and gas, scattered and in clouds, around the stars and in the spaces between them. Our vision is not clear; simple geometric relations between light and distance are incorrect because our observing station is in a fog that unevenly dims the light of the surrounding stars.

Gradually we are learning through studies of colors, and otherwise, how to make corrections for the interstellar absorption. It would not be difficult at all if the absorbing material were uniform. But the clouds of absorption are irregular. It is supposed that some of the greatest irregularities would be apparent to the Andromedan observer. At any rate, our own bird's-eye views of hundreds of external galaxies show immediately the dark lanes between spiral arms, or across them, which indicate the interstellar absorption clouds that irregularly dim the star fields of those distant stellar systems.

In summary, our imaginary bird's-eye view has revealed our system as discoidal in its main body of stars, probably surrounded by a thinly populated spheroidal shell and dominated by a massive globular nu-

cleus, which is some 30,000 light-years from the sun in an accurately measurable direction. Less certainly the view discloses that the Milky Way system is a spiral, perhaps more open in structure than the Andromeda galaxy; it is rotating at high speed, but, even so, 2 million centuries or possibly more will be required for the sun and its neighbors to complete one circuit, to click off one cosmic year. Uncertainty remains as to over-all dimensions of the discoidal galaxy and of its stellar haze, and this uncertainty arises in part from the existence of light-absorbing, mostly nonluminous, interstellar material and from its irregular distribution and its dissimilar effectiveness on light at various wave lengths.

If, for a more distant view of this part of the universe we go off into space several million light-years in a special direction, the Andromeda nebula and our galactic system would look like a pair of galaxies, separated by only a few diameters. And in the same field, apparently also a part of our local group of galaxies, would be the great spiral, Messier 33. A closer inspection from this distant point, and a careful measurement of distances, would show several fainter galaxies associated with these three large systems. Two of them would be the faint companions of the Andromeda nebula—Messier 32 and NGC 205; two of them would be our own satellite-companions, the Large and Small Clouds of Magellan. And there would be at least four other dwarf galaxies, two of them irregular in form, and two or more spheroidal.

The existence of this local cloud of galaxies, in which our system appears to be the big dominating member, seems to be now beyond question, but the census of its membership is not complete. All the known members are within a sphere of a million light-years diameter. Those unknown, or of uncertain membership, include systems wholly or partly concealed by the clouds of absorption near the Milky Way plane. The rating of the great globular clusters is also not yet clear. A hundred globular clusters surround our galaxy, apparently subordinate members of the system, but the larger ones, like Omega Centauri and 47 Tucanae, should perhaps be ranked with the dwarf galaxies. In total luminosity and in mass they are comparable to NGC 205, the faint spheroidal galaxy in the Andromeda group. Our hypothetical Andromedan observer would probably record at least these two giant clusters as dwarf galaxies, if our own procedure with regard to classifying NGC 205 were followed.

Groups like the local "supergalaxy" occur elsewhere in metagalactic space. A dozen rich clusters are known, some of them with hundreds of members, and a score or two of small groups, similar to our own, are already on record. One such is a group of objects in Fornax, in which the brightest are spheroidal; in our group the brightest galaxies are spiral or irregular in form.

Probably there are dwarf galaxies in the Fornax group, but as yet we have not identified them, nor have we found the Magellanic type. Because of the general tendency of the universe to expand and the galaxies and groups of galaxies to recede from one another, it may be that eventually we shall be able to say which faint objects in Fornax are members of the supersystem simply by determining their velocities in the line of sight. If the suspected galaxy is really much more distant than the average of the Fornax group, it will show a bigger "red shift" in the spectrum, a greater velocity of recession, and thus indicate the larger distance and the nonmembership.

On every expedition into remote corners of extragalactic space, it is necessary to equip ourselves with information on giant and supergiant stars. The reason is, obviously, that ordinary stars in far-off places are not recorded on our photographs; they are too dim. We must work with the giants. It may be of interest to consider the following highly luminous stars and types of stars and see how they contribute to knowledge of the metagalaxy:

1. Supernovae
2. S Doradus
3. Novae
4. P-Cygni stars and others

1. *Supernovae.*—"The most energetic catastrophe in the history of the world, unless it be creation itself," is how I would describe the great violence of radiation and motion that accompanies the career of the supernova. Simply defined, a supernova results when a star blows up. Whether the disaster is caused or encouraged by head-on collision with another star or another something, or by the collapse of the star's structure, with the consequent atomic transformation of mass into radiation, or "just happens," we cannot yet say. More observational data are needed and are being obtained. The result of a supernova outburst is the outpouring of light in unparalleled fashion—a spurt of radiation the equivalent at times of 50 million suns and more. The burst of radiation lasts sometimes several days or weeks, quieting down slowly as the months go by. What remains after the flare-up? Perhaps a dense subdwarf star (the collapsed core of the original star); perhaps a hurriedly expanding nebula; perhaps just dust and ashes, and the universe filling up with the dying glow of a radiant moment.

Dr. Fritz Zwicky of the California Institute of Technology has been the leader in recent years in the discovery of supernovae and in speculations concerning them. He thinks that neutrons and neutrinos play an important part in the supernova phenomenon. Certainly supernovae play a significant part in the history of the universe. They are not too uncommon. About 40 are on record, most of them discovered in the past 10 years. Three of them appeared long ago in our

own galactic system. One hypothesis of the origin of the cosmic rays ties them up with the violence of the supernova.

The most distant individual stars yet photographed are some of the supernovae that are in galaxies tens of millions of light-years distant. When more complete records are obtained we shall be able to see if, at maximum brightness, they are sufficiently alike so that their apparent magnitudes at maximum can be used as a practical criterion of distance. At present there seems to be too large a dispersion in the intrinsic luminosities to make supernovae useful criteria in distance measurement in the metagalaxy.

Long before supernovae were recognized, and long before there was the faintest notion of their enormous size as celestial phenomena, they played a very important part in astronomical development and in knowledge of the universe. For it happens that new stars suddenly appearing in 1572 and 1604 were important in the inspiration of two of the great astronomers of that time and of all time—Tycho Brahe, the Dane, and Johannes Kepler. Now we know that these stellar outbursts in Cassiopeia (Tycho's star) and in Ophiuchus (Kepler's *stella nova*) were most probably supernovae. Both stars rose to a brightness comparable with that of the brightest planet; both stars changed explosively 15 magnitudes or more, an increase of brightness of more than a million times.

A third supernova of our galactic system was recorded by the Japanese and Chinese astronomers in 1054. The phenomenon was the parent of the present well-known Crab nebula which is still rapidly expanding as a result of the eleventh-century disaster—eleventh century in our records, but 5,000 years earlier on the cosmic clock.

2. *The supergiant S Doradus.*—The distinction of holding top place as a luminous star has been the lot of an object at the edge of one of the open clusters in the Large Magellanic Cloud. It is a variable star with average luminosity half a million times that of the sun. It is somewhat exceeded in radiation output by supernovae, but they do not last, whereas S Doradus has been continuously radiating for the past half century, pouring out more than 100 trillion tons of light per minute. It must have enormous resources to persist at such high luminosity. Is it perhaps some very slow type of supernova? The variations we now observe are irregular in character, but of no great moment in alleviating the expenditure of radiant energy. The spectrum of the star is of the rare P-Cygni type, which is indicative of unusually hot surface conditions. The Harvard photographic records of this star do not extend much before 1890, but of course there is little reason to suspect that S Doradus has been the supreme supergiant for only the past brief 50 years. Recent photographs with the large southern reflector have shown that stars nearly as bright as

S Doradus are clustered around it, but unfortunately all of them are difficult to study because, notwithstanding their great intrinsic luminosities, the intervening distance of 75,000 light-years dims the light so that even large telescopes can with difficulty make detailed analyses. None of the stars in the solar neighborhood is one-tenth as bright as S Doradus.

3. *Ordinary novae.*—Several times a year, if we pay close attention, we find new stars in our own galactic system, especially in the direction toward the galactic center in Sagittarius. But daylight, clouds, moonlight, and astronomical inactivity contribute to our failure to record more than a few percent of those that we know, from sampling, must be occurring. These new stars, or ordinary novae, behave much like the supernovae described above. But the nova phenomenon is much less violent, and a star is not sacrificed by each outburst. It is likely that the ordinary nova represents the explosive instability of the outer surfaces of a star. There is some indication that before explosion the ordinary novae are slightly subnormal stars of ordinary type. Perhaps this subnormality is at the bottom of the trigger action that sets them off.

But whatever the cause of the novae, it must be recorded as an interesting phenomenon, and one that probably is important in the general history of stars. In our own galaxy, and in the neighboring Andromeda galaxy, these novae appear so frequently that when one thinks back over the past billion years that the earth's crust has existed, one concludes that very many stars have blown up—a large proportion of them. Frequently we have remarked that novation is so common and time has been so long that every star might have blown up once, or will explode during the next billion years—in other words, that evolution, or development, by way of the nova outburst is a major and not a negligible phenomenon in this world.

Evidence is accruing, however, that novation is a recurrent phenomenon. Four or five stars have been novae more than once, and two of them three times since 1860. If this be the true situation—that is, only stars of peculiar character become novae—we may remain even more at ease with respect to the immediate future of our sun. Its character is good and normal. We like to believe that the sun is and always will be only slightly variable (in the sunspot period), and will remain quite dependable, undisturbed by interstellar clouds, unsusceptible to nova-inciting disturbance—at least for the next thousand years while the astronomers are finding out about the universe. A nova-like change in the sun would promptly wipe biology off the earth, if it did not erase the planet altogether.

At maximum the ordinary novae are supergiant stars, more than 10,000 times the luminosity of the sun, but scarcely 1 percent as radiant as the average supernova. When novae appear in external galaxies

they can be used as distance indicators because at maximum brightness the ordinary nova comes to about the same candlepower every time. Comparing the apparent brightness with the real brightness, the distance in light-years can readily be computed. Next to the Cepheid variables, novae are the best criteria for measuring distances of galaxies, providing there are enough found in any given system to stabilize the statistics.

4. *Some other supergiants.*—Two or three magnitudes fainter than the notable S Doradus in the Large Magellanic Cloud are a number of others of the same peculiar spectrum, which are termed the P-Cygni type. There is evidence, not quite conclusive, that these stars are related to the novae, differing most conspicuously, of course, in the property of remaining at high luminosities and not fading away after the impulsive outburst. But in addition to these bluish hot stars we find in the Magellanic Clouds supergiant red stars, almost as bright. Some of them are variable, and some are, indeed, long-period Cepheid variables, 10,000 times as bright as the sun. Many resemble the famous red giants of our neighborhood, Antares and Betelgeuse. A few greatly exceed the local red supergiants in volume as well as in radiation output. Diameters of the order of the radius of Jupiter's orbit, volumes 10 million times that of the sun, are indicated. These preposterous dimensions are derived by knowing the distance of the Magellanic Cloud, the total candlepowers of these supergiant stars, and the spectra which indicate low efficiency as radiators. In order to give out so much radiation, the emitting surfaces must be exceedingly large. The star S Doradus, on the other hand, which is a more efficient radiator, is much smaller and denser than the Antares-like supergiants.

Adjacent to the Small Magellanic Cloud is the great globular cluster, 47 Tucanae, already mentioned as an intermediate between normal galaxies and normal star clusters. Its three brightest stars appear to be typical long-period variable stars, but they are not typical in one respect. Their luminosities at maximum are three or four magnitudes brighter than most long-period variable stars, which are typified by Mira (The Wonderful) Ceti, the first of known variables. It is peculiar, too, that the three supergiant variables in the cluster rise to almost exactly the same magnitude at maximum, and all have periods of about 200 days. This is one of the coincidences that the laws of chance do not easily condone; there must be some deep significance for stars or star clusters in the unusual performance of these supergiants.

Both blue and red supergiants appear sporadically in our own galactic system; probably the occasionally detectable highly luminous stars in external galaxies also belong to various spectral classes. Dr. Hubble has effectively used the luminosities of these invariable stars,

along with the available information on Cepheid variables and ordinary novae, to get the distances of galaxies that are not more than a few million light-years away. If a galaxy is as much as 20 million light-years distant, even these supergiants cannot be individually photographed with present telescopic and photographic equipment, and resort must be made to other photometric means of estimating distances. Ordinary giant stars, like Vega and Arcturus, are not yet photographed in any but the very nearest galaxies, and stars of average mass and luminosity, like the sun, have so far not been photographed outside our own galactic system.

The future of research on galaxies probably depends not so much on the size of telescopes as on the speed and resolution of photographic plates and on other radiation-registering devices. But even without better facilities than those at present available, astronomers have plenty to do in galactic research, for within reach are 1,000 million individual stars in our own galaxy, and at least 10 million other galaxies.

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THE SOUTHERN SPIRAL MESSIER 83.

THE SOUTHERN GLOBULAR STAR CLUSTER 47 TUCANAE.

IS THE LIFE ON THE OTHER WORLDS?[1]

By SIR JAMES JEANS, O. M., D. Sc., LL. D., F. R. S., M. R. I.
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So long as the earth was believed to be the center of the universe the question of life on other worlds could hardly arise; there were no other worlds in the astronomical sense, although a heaven above and a hell beneath might form adjuncts to this world. The cosmology of the "Divina Commedia" is typical of its period. In 1440 we find Nicholas of Cusa comparing our earth, as Pythagoras had done before him, to the other stars, although without expressing any opinion as to whether these other stars were inhabited or not. At the end of the next century Giordano Bruno wrote that "there are endless particular worlds similar to this of the earth." He plainly supposed these other worlds—"the moon, planets and other stars, which are infinite in number"—to be inhabited, since he regarded their creation as evidence of the Divine goodness. He was burned at the stake in 1600; had he lived only 10 years longer, his convictions would have been strengthened by Galileo's discovery of mountains and supposed seas on the moon.

The arguments of Kepler and Newton led to a general recognition that the stars were not other worlds like our earth but other suns like our sun. When once this was accepted it became natural to imagine that they also were surrounded by planets and to picture each sun as showering life-sustaining light and heat on inhabitants more or less like ourselves. In 1829 a New York newspaper scored a great journalistic hit by giving a vivid, but wholly fictitious, account of the activities of the inhabitants of the moon as seen through the telescope recently erected by His Majesty's Government at the Cape.

It will be a long time before we could see what the New York paper claimed to see on the moon—batlike men flying through the air and inhabiting houses in trees—even if it were there to see. To see an object of human size on the moon in detail we should need a telescope of from 10,000 to a 100,000 inches aperture, and even then we should have to wait years, or more probably centuries, before the air was still and clear enough for us to see details of human size.

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[1] Afternoon lecture, Thursday, November 20, 1941. Reprinted by permission from the Proceedings of the Royal Institution of Great Britain, 1941.

To detect general evidence of life on even the nearest of the planets would demand far larger telescopes than anything at present in existence, unless this evidence occupied an appreciable fraction of the planet's surface. The French astronomer Flammarion once suggested that if chains of light were placed on the Sahara on a sufficiently generous scale, they might be visible to Martian astronomers if any such there be. If this light were placed so as to form a mathematical pattern, intelligent Martians might conjecture that there was intelligent life on earth. Flammarion thought that the lights might suitably be arranged to illustrate the theorem of Pythagoras (Euclid, I. 47). Possibly a better scheme would be a group of searchlights which could emit successive flashes to represent a series of numbers. If, for instance, the numbers 3, 5, 7, 11, 13, 17, 19, 23 . . . (the sequence of primes) were transmitted, the Martians might surely infer the existence of intelligent Tellurians. But any visual communication between planets would need a combination of high telescopic power at one end and of engineering works on a colossal, although not impossible, scale at the other.

Some astronomers—mainly in the past—have thought that the so-called canals on Mars provide evidence of just this kind, although of course unintentionally on the part of the Martians. Two white patches which surround the two poles of Mars are observed to increase and decrease with the seasons, like our terrestrial polar ice. Over the surface of Mars some astronomers have claimed to see a geometrical network of straight lines, which they have interpreted as a system of irrigation canals, designed to bring melted ice from these polar caps to parched equatorial regions. Percival Lowell calculated that this could be done by a pumping system of 4,000 times the power of Niagara. It is fairly certain now that the polar caps are not of ice, but even if they were, the radiation of the summer sun on Mars is so feeble that it could not melt more than a very thin layer of ice before the winter cold came to freeze it solid again. Actually the caps are observed to change very rapidly and are most probably clouds consisting of some kind of solid particles.

The alleged canals cannot be seen at all in the largest telescopes nor can they be photographed, but there are technical reasons why neither of these considerations is conclusive against the existence of the canals. A variety of evidence suggests, however, that the canals are mere subjective illusions—the result of overstraining the eyes in trying to see every detail of a never very brightly illuminated surface. Experiments with school children have shown that under such circumstances the strained eye tends to connect patches of color by straight lines. This will at least explain why various astronomers have claimed to see straight lines not only on Mars, where it is just conceivable that there might be canals, but also on Mecury and the largest satellite

of Jupiter, where it seems beyond the bounds of possibility that canals could have been constructed, as well as on Venus, on which real canals could not possibly be seen since its solid surface is entirely hidden under clouds. It may be significant that E. E. Barnard, perhaps the most skilled observer that astronomy has ever known, was never able to see the canals at all, although he studied Mars for years through the largest telescopes.

A more promising line of approach to our problem is to examine which, if any, of the planets is physically suitable for life. But we are at once confronted with the difficulty that we do not know what precise conditions are necessary for life. A human being transferred to the surface of any one of the planets or of their satellites, would die at once, and this for several different reasons on each. On Jupiter he would be simultaneously frozen, asphyxiated, and poisoned, as well as doubly pressed to death by his own weight and by an atmospheric pressure of about a million terrestrial atmospheres. On Mercury he would be burned to death by the sun's heat, killed by its ultraviolet radiation, asphyxiated from want of oxygen, and desiccated from want of water. But this does not touch the question of whether other planets may not have developed species of life suited to their own physical conditions. When we think of the vast variety of conditions under which terrestrial life exists on earth—plankton, soil bacteria, stone bacteria, and the great variety of bacteria which are parasitic on the higher forms of life—it would seem rash to suggest that there are any physical conditions whatever to which life cannot adapt itself. Yet as the physical states of other planets are so different from that of our own, it seems safe to say that any life there may be on any of them must be very different from the life on earth.

The visible surface of Jupiter has a temperature of about —138° C., which represents about 248 degrees of frost on the Fahrenheit scale. The planet probably comprises an inner core of rock, with a surrounding layer of ice some 16,000 miles in thickness, and an atmosphere which again is several thousands of miles thick and exerts the pressure of a million terrestrial atmospheres which we have already mentioned. The only known constituents of this atmosphere are the poisonous gases methane and ammonia. It is certainly hard to imagine such a planet providing a home for life of any kind whatever. The planets Saturn, Uranus, Neptune, and Pluto, being farther from the sun, are almost certainly even colder than Jupiter and in all probability suffer from at least equal disabilities as abodes of life.

Turning sunward from these dismal planets, we come first to Mars, where we find conditions much more like those of our own planet. The average temperature is about −40° C., which is also −40° on the Fahrenheit scale, but the temperature rises above the freezing point

on summer afternoons in the equatorial regions. The atmosphere contains at most only small amounts of oxygen and carbon dioxide, perhaps none at all, so that there can be no vegetation comparable with that of the earth. The surface, in so far as it can be tested by a study of its powers of reflection and polarization, appears to consist of lava and volcanic ash. To us it may not seem a promising or comfortable home for life, but life of some kind or other may be there nevertheless.

Being at the same average distance from the sun as the earth, the moon has about the same average temperature, but the variations around this average temperature are enormous, the equatorial temperature varying roughly from 120° C. to −80° C. The telescope shows high ranges of mountains, apparently volcanic, interspersed with flat plains of volcanic ash. The moon has no atmosphere and consequently no water; it shows no signs of life or change of any kind, unless perhaps for rare falls of rock such as might result from the impact of meteors falling in from outer space. A small town on the moon, perhaps even a large building, ought to be visible in our largest telescopes, but, needless to say, we see nothing of the kind.

Venus, the planet next to the earth, presents an interesting problem. It is similar to the earth in size but being nearer the sun is somewhat warmer. As it is blanketed in cloud we can only guess as to the nature of its surface. But its atmosphere can be studied and is found to contain little or no oxygen, so that the planet's surface can hardly be covered with vegetation as the surface of the earth is. Indeed, its surface is probably so hot that water would boil away. Yet no trace of water vapor is found in the atmosphere, so that the planet may well be devoid of water. There are reasons for thinking that its shroud of clouds may consist of solid particles, possibly hydrates of formaldehyde. Clearly any life that this planet may harbor must be very different from that of the earth.

The only planet that remains is Mercury. This always turns the same face to the sun and its temperature ranges from about 420° C. at the center of this face to unimaginable depths of cold in the eternal night of the face which never sees the sun. The planet is too feeble gravitationally to retain much of an atmosphere and its surface, in so far as this can be tested, appears to consist mainly of volcanic ash like the moon and Mars. Once again we have a planet which does not appear promising as an abode of life and any life that there may be must be very different from our own.

Thus our survey of the solar system forces us to the conclusion that it contains no place other than our earth which is at all suitable for life at all resembling that existing on earth. The other planets

are ruled out largely by unsuitable temperatures. It used to be thought that Mars might have had a temperature more suited to life in some past epoch when the sun's radiation was more energetic than it now is, and that similarly Venus can perhaps look forward to a more temperate climate in some future age. But these possibilities hardly accord with modern views of stellar evolution. The sun is now thought to be a comparatively unchanging structure, which has radiated much as now through the greater part of its past life and will continue to do the same until it changes cataclysmically into a minute "white dwarf" star. When this happens there will be a fall of temperature too rapid for life to survive anywhere in the solar system and too great for new life ever to get a foothold. As regards suitability for life, the earth seems permanently to hold a unique position among the bodies surrounding our sun.

Our sun is, however, only one of myriads of stars in space. Our own galaxy alone contains about 100,000 million stars, and there are perhaps 10,000 million similar galaxies in space. Stars are about as numerous in space as grains of sand in the Sahara. What can we say about the possibilities of life on planets surrounding these other suns?

We want first to know whether these planets exist. Observational astronomy can tell us nothing; if every star in the sky were surrounded by a planetary system like that of our sun, no telescope on earth could reveal a single one of these planets. Theory can tell us a little more. While there is some doubt as to the exact manner in which the sun acquired its family of planets, all modern theories are at one in supposing that it was the result of the close approach of another star. Other stars in the sky must also experience similar approaches, although calculation shows that such events must be excessively rare. Under conditions like those which now prevail in the neighborhood of the sun, a star will experience an approach close enough to generate planets only about once in every million million million years. If we suppose the star to have lived under these conditions for about 2,000 million years, only one star in 500 million will have experienced the necessary close encounter, so that at most one star in 500 million will be surrounded by planets. This looks an absurdly minute fraction of the whole, yet when the whole consists of a thousand million million million stars, this minute fraction represents two million million stars. On this caculation, then, two million million stars must already be surrounded by planets and a new solar system is born every few hours. The calculation probably needs many adjustments; for instance, conditions near our sun are not necessarily typical of conditions throughout space and the conditions of today are probably not typical of conditions in past ages. Indeed, on any reasonable view of stellar evolu-

tion, each star must have begun its life as a vast mass of nebulous gas, in which state it would present a far more vulnerable target than now for disruptive attacks by other stars. Detailed calculation shows that the chance of a star's producing planets in this early stage, although not large, would be quite considerable, and suggests, with a large margin to spare, that although planetary systems may be rare in space, their total number is far from insignificant. Out of the thousands or millions of millions of planets that there must surely be in space, a very great number must have physical conditions very similar to those prevailing on earth.

We cannot even guess whether these are inhabited by life like our own or by life of any kind whatever. The same chemical atoms exist there as exist here and must have the same properties, so that it is likely that the same inorganic compounds have formed there as have formed here. If so, we would like to know how far the chain of life has progressed, but present-day science can give no help. We can only wonder whether any life there may be elsewhere in the universe has succeeded in managing its affairs better than we have done in recent years.

SOLAR RADIATION AND THE STATE OF THE ATMOSPHERE[1]

By Harlan True Stetson
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[With 4 plates]

For a week before the great aurora of September 18, 1941, with the attendant wide-spread disturbances to radio communication, the sun had been heralding the event. Although the sunspot cycle has been definitely on the wane since 1937, the week preceding the 18th presented one of the largest groups of spots seen in recent years, so conspicuous, in fact, that it was visible to the naked eye through suitable dark glasses. The forecasting of interruptions to radio communication is of increasing significance in these days of national defense, but the ability to foresee communication interruptions has been a recent result of intersified interest in the stduy of relationships between solar disturbances and terrestrial atmospheric conditions.

The sun is a typical star of rather ordinary proportions, but because of our proximity to it, the sun is the one star upon whose radiations activities on the earth are unalterably dependent. Military campaigns as well as agriculture since the dawn of civilization must be governed by the seasons for which the changing declination of the sun is the major astromonical factor. With the conquest of the upper air for transportation and the use of atmospheric electric waves for world-wide radio communication, the study of the sun's radiations in relation to our atmosphere has become an astronomical problem of far more than academic interest.

Not a day passes but that our United States Naval Observatory in cooperation with other observatories has a complete photographic record of the conditions of the sun's surface. When a huge solar storm is in the making, communication agencies are forewarned days in advance of probable periods of interrupted radio reception. The question of the relation of sunspots to the forecasting of weather is still in a controversial stage, but meteorologists are beginning to realize the increasing significance of conditions in the high atmosphere to the

[1] Reprinted by permission from The Scientific Monthly, vol. 54, June 1942.

lower regions in which our weather appears to arise. All weather is fundamentally traceable to solar radiation. The amount and the character of this radiation, particularly in its relationship to atmospheric phenomena, merits more detailed consideration.

From observations at the Smithsonian Institution, the amount of energy that the sun emits has been measured with such precision that we know not only the quantity of heat and light emitted, but that this quantity varies from time to time by some 2 or 3 percent. The average energy received by the earth from the sun is about 450 million million horsepower. Because of the relatively insignificant size of the earth, and also the great distance that separates us from the sun—a distance of 93 million miles—our planet can intercept but about one two-billionth of the total solar output. Even so, if we stop to consider what the cost to us would be were we charged for a year's service of heat and light from the Solar Utilities Power and Light Company, we would find our indebtedness mounting to staggering proportions. At a price of 1¾ cents per kilowatt hour, the annual budget that would have to be allowed for sunshine for the continental United States alone would represent an expenditure of 327 quadrillion dollars. Such figures are indeed difficult to imagine. If we change our picture to a more restricted one, we can say that the cost of sunshine for Greater New York at the above figure would amount to approximately 100 million dollars for the average day. Fortunately for us, millions of years ago this same sunshine provided the energy for growing the vast tropical forests of the carboniferous era. The carbon in those fallen tree trunks that we are mining today in the form of coal together with the water power provided by the vast irrigating systems maintained by the sun's radiation is the source for the maintenance of our public utilities and industries today. It is an interesting question as to how long the sun can maintain its present output of radiation and how far into the future we may rely upon its ability to furnish us with this all-essential source of energy. It appears probable that within the hot interior of the sun, which may be estimated in terms of millions of degrees, an atomic transmutation is taking place that has been going on for millions of years and is likely to continue for a long time to come. Through an ingenious carbon cycle recently worked out by Professor Bethe, of Cornell University, we picture the ultimate transformation of hydrogen into helium with the continual release of energy in the form of radiation that represents a loss of mass to the sun of some 4,200,000 tons every second. We scarcely need worry, however, about the deterioration of the fuel supply while the sun has about 2,000,000,000,000,000,000,000,000,000 tons of matter still left in it.

If we analyze the radiation from the sun we discover that it covers a wide range of wave lengths. Certain of these wave lengths or fre-

quencies produce their own special effects upon the earth and its atmosphere.

We are all familiar with the fact that if sunlight is split into its component colors by means of a spectroscope we can see a large variety of the radiations represented by the various parts or colors of the solar spectrum. The visible range to which the eye responds represents frequencies extending from 400 million million cycles per second to a frequency just about double this, or 800 million million cycles per second. The sensation of the higher of these two frequencies is that of violet light, and the sensation produced by the 400 million million cycle frequency is that of deep red light. In between these two extremes of the spectrum fall the intervening colors. But outside this so-called visible range to which the eye responds there is a vast scale of radiations both beyond the red end of the spectrum, which we call the infrared, and far down below the violet, which we call the ultraviolet.

By means of the photographic plate, we can extend the map of the spectrum in either direction. Far out beyond the red end are heat radiations from the sun that may be measured with the thermopile or the bolometer. Today much research is being done in measuring the extremely short waves, or high-frequency radiations out beyond the violet, for the ultraviolet is coming to have increasing importance not only from the point of view of health but from the point of view of the radio engineer.

The sunlight which we measure or analyze at the earth's surface is, however, seriously modified by the absorption introduced by the constituents of our own atmosphere. As we all know, the earth's atmosphere consists of nearly ¼ oxygen and ¾ nitrogen. There is a sprinkling of carbon dioxide with a bit of argon, neon, crypton, xenon, and a trace of helium. Here at the earth's surface we can count on a little more than 1 percent of water vapor. For a thorough mixing of the elements of this atmosphere and the maintenance of its temperature as well as the variation in its temperature, we rely upon the sun. Occasionally we have vividly impressed upon us the relationship of our atmosphere to disturbances on the sun, by displays of aurorae or the Polar Lights, often flaming gorgeously red and stretching 100 miles above the earth. These glowing electric discharges advertise the lofty air swarming with the traffic of electrons, ions, and particles, jostling one another as they are excited by radiations from the sun peculiar to the occurrences of sunspot activity.

Observations with the spectroscope indicate that there is much radiation at the extreme ultraviolet end of the spectrum to which the earth's atmosphere is completely opaque. A great deal of the absorption of this region of the solar spectrum of very short wave lengths is caused by a layer of ozone which exists at an average height

of about 22 kilometers, but which probably occupies a region extending from 15 to 35 kilometers. If all the ozone in this region were to be brought to the standard conditions of temperature and pressure of our atmosphere at the earth's surface, it would represent a layer of only 2 to 3 millimeters in thickness. Yet this small amount of ozone is the defense between us and extremely dangerous radiations in the ultraviolet region of the sun's light. Were the absorption, however, of this region of the solar spectrum even a little greater than it is, we should be deprived of that small amount of ultraviolet light filtering through our atmosphere that is so essential for health and the production of our sunshine vitamin D. Whether or not variations in the sun's radiation are sufficiently great or changes in the absorption of the earth's atmosphere sufficiently large to bring about dangerous variations in the production of vitamin D in living organisms at the earth's surface is an interesting question for speculation and for investigation.

We can be confident, however, that it is a fortunate combination of the sun and our atmosphere that makes life on the earth possible. The sun not only radiates its health-giving sunshine, but it also emits literally death-dealing rays. Were it not for the protecting shield of the earth's atmosphere, the sun would be the annihilator of us all. The atmosphere provides on the one hand oxygen for maintaining life, and on the other hand protects us from the highly penetrating rays. It is a sort of a buffer state, the very top of which receives a violent bombardment of high-frequency radiations from the sun, and the lower layers of which form a blanket that enables the earth to retain during the night much of the warmth generated by the sunshine that has penetrated through it, thus mitigating the extremes of temperature between night and day to which the earth would otherwise be subjected.

If we look at a cross section of the earth's atmosphere, it may for convenience be divided into three zones or layers in which the stratosphere occupies the middle ground. The region below the stratosphere is that which contacts our immediate surroundings and provides the winds and atmospheric currents, giving rise to all our weather. We call this lower region comprising perhaps the first 5 or 6 miles the troposphere. The region above the stratosphere is the ionosphere. If we send a recording thermometer aloft, we find that while passing through the troposphere the temperature steadily falls until a height of 10 or 12 kilometers is reached, when the temperature reaches the extremely low value of -55° C., or some 68° below zero Fahrenheit. Strangely enough, for the next 30 miles or so there appears to be little change in temperature. This is the region of the stratosphere. The weather forecaster for the stratosphere would have a relatively simple task, for day after day, year

in and year out, his prognostications would be "clear and cool," and his forecasts would be 100 percent correct. At a height of 60 kilometers or some 40 miles, the temperature would begin to rise again. Recent investigations give some evidence that at extreme heights, up where the auroral fires play, temperatures of 1,000° C. have to be postulated to account for the presence of the ionized oxygen that is there. The extremely rarefied condition of this upper atmosphere, however, calls for perhaps a quite different interpretation of temperature than that to which we are ordinarily accustomed when determining temperatures by the thermometer at the earth's surface.

Ascending through the cross sections of the atmosphere, we find there is a rapid decrease in the amount of atmospheric pressure. Within the first 3 miles from the earth's surface, half the total

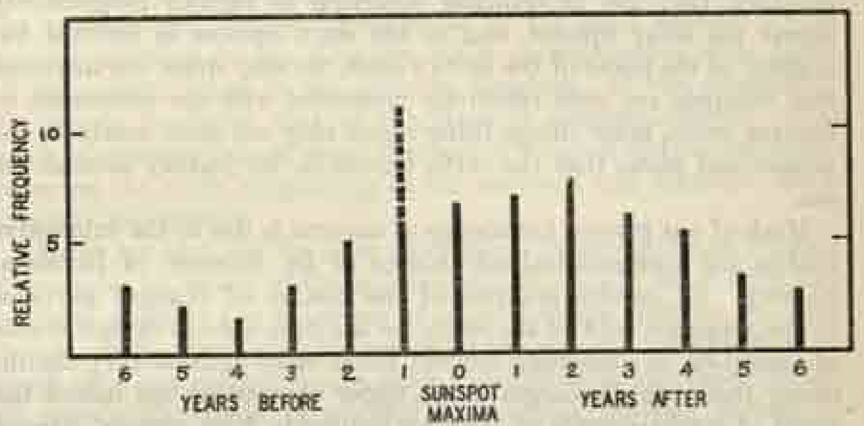

FIGURE 1.—Relative frequency of occurrences of aurorae at the Blue Hill Observatory before and after years of sunspot maxima.

amount of oxygen and nitrogen, the principal atmospheric ingredients, are included. The limiting height to which the thinning atmosphere extends is somewhat difficult to fix. Perhaps we should place it at 200 to 300 miles, although recently Dr. Carl Störmer has observed auroral streamers reaching to heights of 600 kilometers or more. Where auroral streamers go, some of the thin atmosphere must extend.

If we make a chart of the numbers and occurrences of aurorae we find there seems to be a curious connection between the frequency and brightness of auroral displays and the state of the sun as marked by the appearance of sunspots. Professor Brooks, director of the Blue Hill Observatory, has kindly allowed me access to the records made of aurorae at that station for the last 30 years. Utilizing the observations of the brighter aurorae, we may make a graph showing the variations in the auroral frequencies occurring in years

distributed with respect to the maximum occurrences of sunspots. The fewest number of aurorae appear to occur from 4 to 6 years before or after the years marking sunspot maxima. The time when aurorae appear most frequently would seem to be about 2 years after the passing of the maximum of sunspots. These results corroborate rather well those of a longer series of observations tabulated by Dr. Chree extending for over 100 years, or from 1750 to 1877.

The fact that aurorae occur with far greater frequency during years when sunspots are more numerous than during the years when there is a scarcity of sunspots suggests that the electrical effect in the upper atmosphere is something for which a disturbed solar surface is responsible. There is, I believe, a good reason for the fact that the maximum in the auroral displays occurs a year or two after the year of most sunspots. As sunspots begin to wane in numbers, they are nevertheless occurring in regions progressively nearer the solar *equator*, and as the sun's equator is inclined but slightly to the plane of the earth's orbit, we may draw the inference that sunspots are most effectively associated with the occurrence of aurorae when, other things being equal, they are most nearly in the geometrical plane that the earth travels in its journey around the sun.

Much of our present knowledge of aurorae is due to the exhaustive studies and mathematical calculations of Dr. Störmer, of Blindern, Norway. By careful analysis of the motion of charged particles in the magnetic field of the earth, he has been able to deduce tracks of ionization so simulating auroral forms as to indicate very significantly that such discharges in the upper atmosphere are indeed the result of bombardments of electrons coming in from outside, warped by the magnetic field of the earth. In endeavoring to express such phenomena on an electronic hypothesis we may well look at the sun, therefore, for a consideration of the character of sunspots and so trace any possible mechanism by which corpuscular charges might be ejected in the region of the sunspots themselves.

When we look at an enlarged view of a sunspot and analyze the light from it, we find that the dark interior center is surrounded by a turbulent area. Photographs taken in the light emitted by hydrogen at a particular frequency reveal that there are whirling masses of gas, arranging themselves in veritable vortices. There is every indication, then, that a sunspot is in reality a terriffic solar hurricane. It was in 1908 that the late Dr. George Ellery Hale, the founder and director of the Mount Wilson Observatory, first observed that sunspots were giant cyclones in the sun's atmosphere. They are indeed very similar in their formation to the tropical hurricanes that originate in the West Indies and sweep northward.

With photographic emulsions made especially sensitive to the red

light emitted by hydrogen, there may be photographed on a moving film the entire solar surface so far as it is covered by bright luminous hydrogen clouds. The resulting representations of the sun appear very different from photographs make in ordinary light. Not only are large clouds of hydrogen gas discernible all over the sun, but in the neighborhood of sunspots they often seem to be swept into the heart of the spot as if they were caught in the center of a whirlpool. Such an appearance might be presented by the top of a terrestrial cyclone or tornado if photographed from a stratospheric balloon. The dark center of the spot forms the center of the vortex; the outlying shaded region that characterizes the so-called penumbra of the sunspot would represent the turbulence bordering upon the central funnel about which the atmospheric particles are rapidly rotating. Thus we see there is a close analogy between the meteorology of tropical cyclones and that of sunspots. To carry the analogy still further, spots north of the sun's equator are in general whirling in one direction while corresponding spots south of the equator whirl in the opposite direction. If the rotation of the one is clockwise, that of the other is counterclockwise. This again is characteristic of the differences of rotation of tropical hurricanes on the earth originating in the northern and southern hemispheres, respectively.

Had it not been for the trick of splitting up sunlight into isolated frequencies by means of the spectroscope, we should never have had pictures showing the existence of solar vortices such as we have today. In the ordinary photograph of the sun, the light emitted by every chemical element in the sun's atmosphere is clamoring to tell its story. The result is revealed in a rather jumbled picture of what is happening on the sun. The spots show up as dark regions only when the light-emitting power of every element of the sun is damaged in the vicinity of these violently disturbed regions.

The spectroscope is very much like a highly selective radio receiving set. The sun is a high-powered station sending out light, broadcast in all the wave lengths and frequencies. When we look at the sun or photograph it with a telescope alone, we are using all the light and are, so to speak, operating a radio receiver which admits all frequencies at once. Thus we get a composite but very jumbled picture of what is happening on the sun's surface as far as details are concerned. By means of the spectroscope, however, the photographic apparatus, to continue our analogy, must be tuned to a single frequency such as the 470 million megacycle frequency that the red line of hydrogen emits. Tuned to this frequency the spectroscope stills the tumult of all other elements and lets hydrogen tell its own story. It is then that we obtain the clear photographs conveying so beautifully the detailed information about the vortical whirls around the solar storm

centers that would otherwise be lost in the jumble of too many story tellers.

It has long been known that the frequencies of light waves are distorted if there is a powerful magnetic field surrounding the light source. This had been demonstrated in the laboratory shortly after the reason for such a phenomenon had been given by Zeeman in 1894. When the Mount Wilson observers first examined and actually measured the frequency of light coming from the centers of sunspots, it was found to have changed frequency in exactly the way that light waves are distorted in the laboratory when a powerful electromagnet is placed around the source of light being examined. If additional proof were needed for the explanation of the

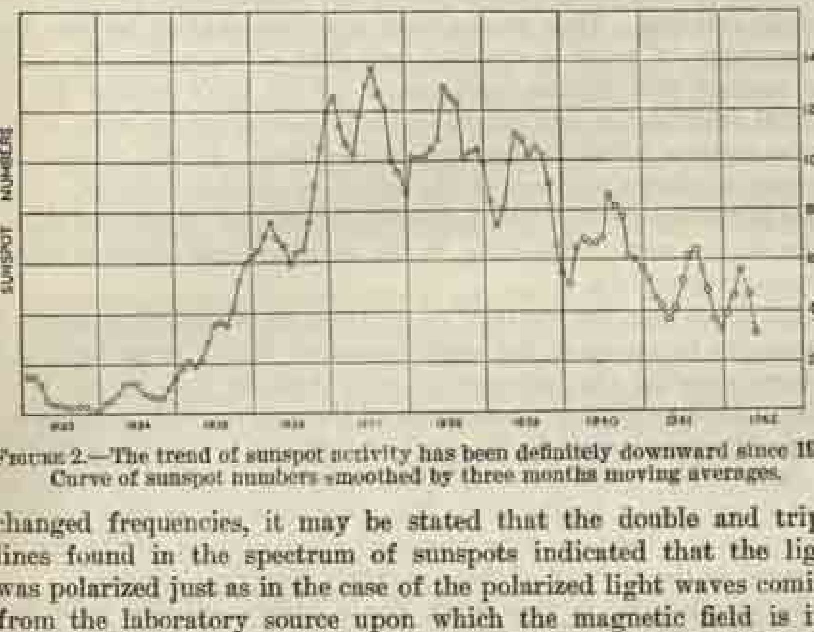

FIGURE 2.—The trend of sunspot activity has been definitely downward since 1937. Curve of sunspot numbers smoothed by three months moving averages.

changed frequencies, it may be stated that the double and triple lines found in the spectrum of sunspots indicated that the light was polarized just as in the case of the polarized light waves coming from the laboratory source upon which the magnetic field is impressed. Thus came the startling revelation that sunspots were not only terrific hurricanes but every center was in itself a powerful magnet. Since a magnetic field may exert a repulsing effect upon swiftly moving electrons, we see some reason that charged electric particles can be actually hurled from sunspot centers at velocities which may carry them through space into the earth's atmosphere, thus ionizing the upper regions of the air in a way that would produce auroral displays. In the light of such a mechanism, therefore, we see a possible reason why aurorae occur in greater numbers and at greater brilliance at times when these solar storms occur most frequently.

With the new unsurpassed equipment installed at the McMath-Hulbert Observatory of the University of Michigan, motion pictures of the

sun's surface have been made on many different frequencies of the sun's radiation. These cinematographic records promise more material for the intense study of the behavior of the solar surface than has ever before been available. Some of the movements in the high solar atmosphere over the regions of sunspots revealed by this new process of recording continuous motion at present defy explanation and may yet completely revolutionize our ideas of the sun's behavior pattern.

Perhaps the terrestrial effect that has most nearly paralleled the sunspot cycle is the variation in the state of the earth's magnetic field. For over 100 years, it has been definitely known that the direction of the compass needle and the intensity of the earth's magnetic field show definite relationships. In the years when sunspots are most numerous magnetic disturbances are most frequent and appear with marked intensity. The years when sunspots are most numerous follow with more or less regularity an interval of somewhat over a decade between the times of maximum sunspot activity. This solar cycle, or sunspot period as we sometimes call it, is usually conceded to be on the average of about 11.3 years duration. An examination of a graph will show that sometimes the interval between maxima may be as short as 9 years and on occasion as long as 17 years.

The last maximum of sunspots was passed in 1937 and we are well on our way on the down side of the cycle. It was not until the more recent discovery of an ionized region in the upper atmosphere of the earth that any real explanation appeared as to why sunspots and changes in the earth's magnetic field should show so close a parallelism.

Everyone knows in a general way that the earth is a magnetic sphere. That the compass needle does not point true north except in various restricted parts of the globe is also a fact which is generally recognized. Perhaps comparatively few who are not geomagneticians realize that the compass needle is constantly wandering back and forth every day by a slight amount. When the sun rises in the east, the north end of the compass needle turns slightly toward that direction. By noon when the sun is south, it is pointed in its normal position. Then in the afternoon as the sun wanders and sets in the west, the compass needle wanders likewise to the west, coming back again to its normal position about midnight when the sun is below the northern horizon. This goes on day after day, month after month—but during the years when sunspots are most numerous these daily excursions of the compass needle will on the average be twice as great as during the years when sunspots are lacking. These diurnal wanderings of the compass needle can now be roughly explained as due to the effects of ionization of the upper atmosphere by sunlight. As the electric charges become separated in the process of ionization f the omlecules of nitrogen and oxygen under the bombardment of ultraviolet light from the sun, the movements of these ions create a perceptible current, deflecting

the compass needle from its normal magnetic position. We may infer, therefore, that at times of sunspot maxima the number of these ions in the upper air is materially increased, producing a more marked magnetic effect. The strength of the magnetic field of the earth, therefore, may be considered as increasing and decreasing with the variation in the intensity of the ionization of the upper air that changes with sunspot occurrences. Most of our knowledge of the ionized region has come about through the invention of the radio.

In the early days of wireless, it was thought that electric waves which carried telegraph messages without wires traveled in straight lines over the earth, just as light waves do. With this conception one could never hope to communicate over very great distances, since the curvature of the earth would prevent the passage of the waves as the earth's huge bulk bulged into the communication path. The earlier wireless engineers thought that only by building higher and higher antenna towers could one ultimately hope to communicate over the thousands of miles that would make transoceanic wireless possible.

Of course, these early crude notions about the way in which electric waves travel were erroneous. Such, nevertheless, is the way in which science has groped into the unknown. Somebody experimenting with wireless and listening in found himself quite unconsciously eavesdropping on Marconi waves from the other side of the Atlantic. Instantly the thought about how wireless waves travel had to be changed. Evidently the electromagnetic waves followed the curvature of the earth and did not travel in straight lines after all. This led Professor Kennelly of Harvard to postulate that there must exist high above the earth's surface, perhaps 100 miles or so up, an electrified conducting layer from which the electromagnetic waves emitted from the powerful antennae were reflected back to earth. The earth's upper atmosphere, therefore, in his mind formed a conducting layer and imprisoned the radio waves between the earth's surface and space outside. A few months after Professor Kennelly published his hypothesis, the English scientist, Oliver Heaviside, announced a similar conclusion quite independently. In honor of these two distinguished men this upper region of the earth's atmosphere that is electrically ionized is commonly referred to as the Kennelly-Heaviside layer, also designated as the E layer.

If we look at a diagram (pl. 2) which presents a vertical section of the earth and its atmosphere, we see that this Kennelly-Heaviside layer exists at an altitude of from 100 to 130 kilometers. Radio waves emitted from a sending station in all directions arriving in this ionized region have their velocity and direction changed as they penetrate farther and farther into the region, until at length they are bent back to earth again, reaching receiving stations hundreds and sometimes thousands of miles from the source whence they were broadcast.

This region lies far above the stratosphere and generally above the region that is usually regarded as that where ozone is manufactured. This E layer is particularly favorable for reflecting or turning back radio waves of the frequencies which are most generally used for commercial broadcasting in connection with our entertainment programs. Radio waves of much shorter wave lengths or of higher frequencies penetrate and actually traverse through this region until they reach what appears to be another ionized region called the F layer, originally postulated by Professor Appleton in England. This F layer lies some 200 kilometers high or in the territory where auroral streamers stage their gorgeous displays. If the ionization of these upper regions is more intense as we near the period of maximum sunspot activity, one might well expect that some change might be observed in connection with radio transmission.

Anticipating a new field of research, a Boston radio engineer, G. W. Pickard, and myself became interested in the making of quantitative measurements of radio reception during the sunspot maximum of 1928 in an endeavor to discover if such anticipated effects on radio communication could be measured. After a few years' observations, it appeared to be evident that when solar activity increased the field strength of a Chicago broadcasting station observed in Boston notably weakened, whereas as sunspots became less numerous there was a marked increase in the intensity of the radio waves from Chicago. A similar investigation carried on during the decline of sunspots from 1930 to 1932 between Chicago and the Perkins Observatory of Delaware, Ohio, yielded data to indicate that with a decrease of sunspots from a monthly average of 60 at the beginning of 1930 to a monthly average of about 10 in 1932, radio reception increased sixfold in its intensity.

Continued observations of the Chicago-Boston field strengths in recent years have continued to substantiate the general effect earlier observed. While there may be a 600 percent change in the field strengths between a sunspot maximum and a sunspot minimum, this does not mean that the degree of ionization in the Kennelly-Heaviside layer has been altered by this amount. The field strength of a radio wave at a given distance for a given frequency depends upon the angle of reflection or refraction which in turn is dependent upon the degree of ionization. Field strength also depends upon the absorption of the waves, which is a function of the conductivity. Appleton has estimated from his observations that the ionization and the electrical conductivity of the E and F regions in passing from sunspot maximum to sunspot minimum have shown variations of 50 to 60 percent implying that the solar ionizing agent (ultraviolet light) responsible for the formation of these regions in the ionosphere varies from 120 to 150 percent during the sunspot cycle.

We thus see that radio becomes a sensitive and extremely useful tool in recording changes of degree of ionization of the upper atmosphere. When we observe radio field strengths at long distances we are in a way tracing an integrated effect throughout the whole transmission path for a given frequency.

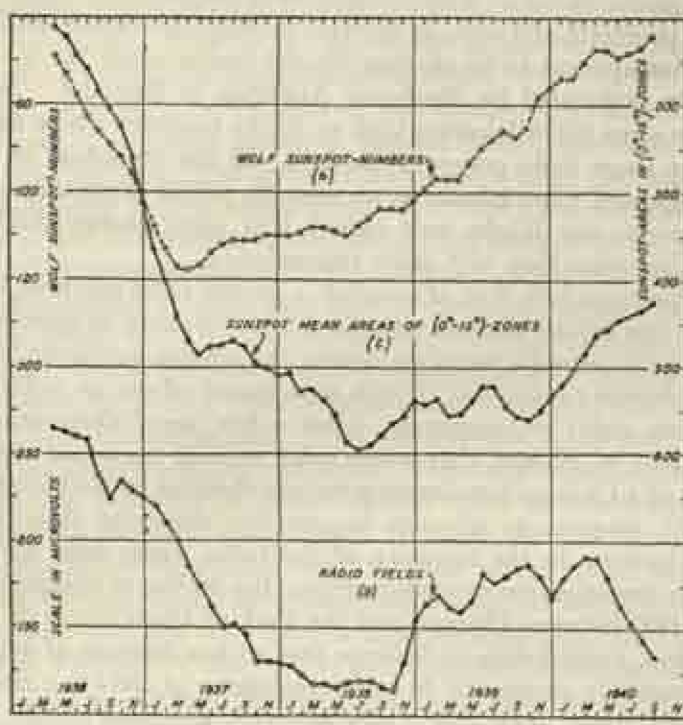

FIGURE 3.—Trend of radio field strengths of WBBM received at Boston compared with sunspot activity 1936–1940. Top curve (*b*) represents sunspot numbers over entire disk of sun; middle curve (*c*) represents variation in areas of sunspots of zones of solar latitude 0° to ±15° either side of the sun's equator; lowest curve (*a*) represents variation in radio field strengths corrected for seasonal and diurnal variations. The fact that the lowest curve parallels closely sunspot activity in the 0° to ±15° zones suggests effect of solar disturbances is greatest when spots are near solar equator.

Another way in which we gain important information as to the sun's effect upon the upper atmosphere is by making radio soundings from day to day. This method, which has been in use for some years at the National Bureau of Standards, at the Department of Terrestrial Magnetism of the Carnegie Institution in Washington and elsewhere, consists in sending up a radio pulse of known frequency and recording its return from the reflecting layer. The time elapsed while the wave was traveling this path to the ionosphere and back is measured with high precision on an oscillograph. Assuming that the radio wave travels with the velocity of light, one can calculate

from the elapsed time the height to which the pulse ascended before it was turned back by the ionosphere.

Soundings made of the ionosphere reveal different conditions at various times, displaying marked changes in the ionic density that are dependent upon the hour of the day and the season of the year. Routine radio soundings include changing the frequency at which the radio pulse is emitted. If the frequency is sufficiently increased, the shorter and more penetrating waves may pass completely through the ionized layer and not return. When such a frequency is attained, it is known as the critical frequency.

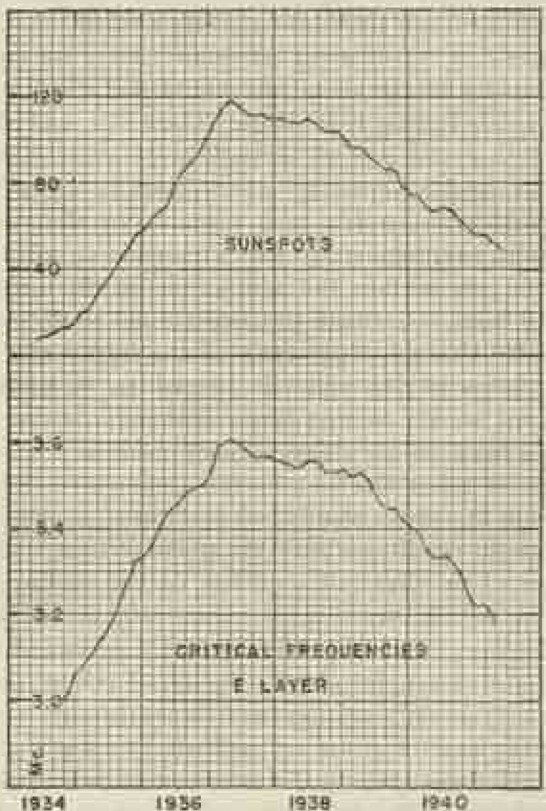

FIGURE 4.—Critical frequencies follow sunspots. Curve smoothed by 12-month moving averages.

The close relation between the observed critical frequencies and the rise and fall in solar activity marked by sunspot numbers has been so apparent during the last 10 years that the National Bureau of Standards now undertakes to predict 3 months in advance the best usable frequencies for radio communication based upon the sunspot cycle.

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During the last few years of sunspot activity, there have been occasions when remarkable fade-outs have occurred in radio communication. In several of these instances extraordinary explosions have occurred on the sun simultaneously with the interruption of all radio communication in general. It would appear that the intense ionizing radiation from the region of the sun where these eruptions occur reaches the earth with the velocity of light and of sufficient intensity to disturb immediately the ionized layer, confusing the reflection of radio waves, and thereby resulting in these fade-outs which sometimes last for an hour or more. Records at magnetic observatories show that during such instances characteristics of the earth's magnetic field are likewise suddenly altered.

Could we visualize the ethereal substance of the ionosphere as we visualize the surface of the ocean, we should find times when terrific storms were raging in this ionosphere. Here ions and electrons are being hurled hither and yon as through some great electrical wind played upon its surface, creating waves literally miles high. Frequently the turbulence attains such proportions that no reflecting surface for radio commmication seems possible at all. When disturbances on the sun subside, the undulations in the ionosphere may quiet down and there is a return to more normal conditions for communication traffic through this ocean of the upper air.

While knowledge of the sun has helped us to understand the vagaries of radio, we are coming to see that radio is one of the most important tools for learning about what happens on the sun and how disturbances there affect the ions in this upper air. Perhaps some day, even though the sky is cloudy, we shall have a sufficient number of reports of radio conditions over the globe so that we can form a very good idea as to what is happening on the surface of the sun by the way in which world-wide radio communication behaves. Unlike the telescope, radio apparatus does not go out of commission when the sky is overcast, for electric waves, of course, pass through the clouds as easily as ordinary daylight comes through window glass.

Concerning the exact method or methods by means of which the sun produces all these electric disturbances of the upper air with the concomitant magnetic variations in the earth, we still lack a great deal of knowledge. The fact that the ultraviolet radiation from the sun is the major factor in producing this ionization appears a reasonable assumption. Whether or not, in addition to the effect of the ultraviolet light, streams of charged particles also emanate from the sun in the regions of sunspots is perhaps still debatable, yet there is accumulating evidence that in addition to the wave radiation from the sun there is also a particle radiation that is primarily responsible for the violent magnetic disturbances such as accompanied the marked solar activity of Easter week in 1940. The elaborate

mathematical work of Dr. Störmer, in calculating the movements of hypothetical charged particles from the sun striking the upper atmosphere of the earth and thereby producing aurorae, would certainly seem to favor the idea that corpuscular radiation of some sort is responsible for this phenomenon.

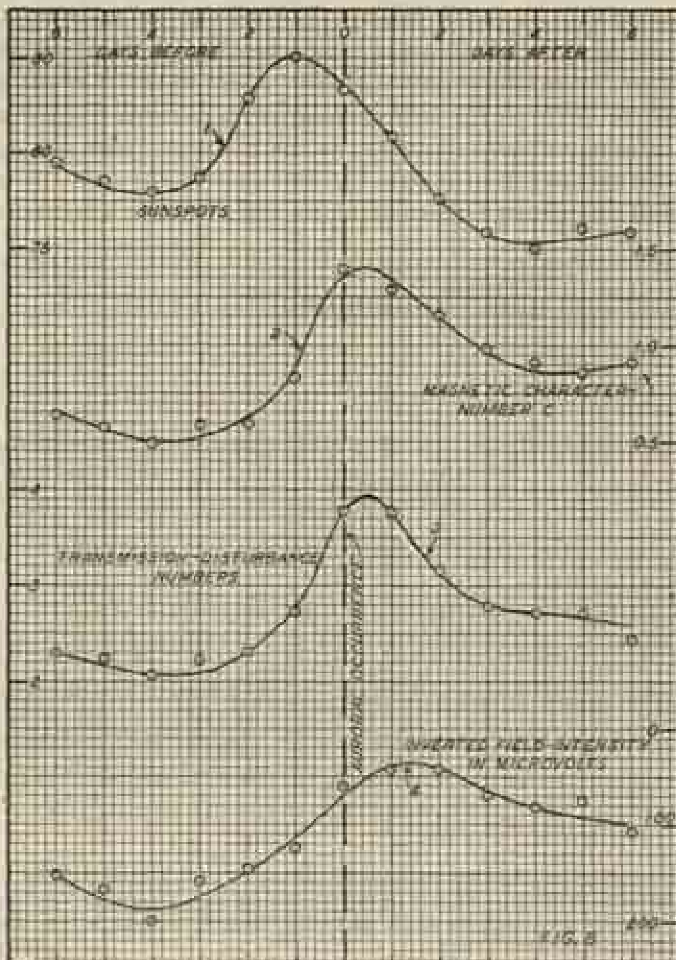

FIGURE 5.—Curve showing correspondence between sunspot activity, terrestrial magnetic changes, disturbances in the F layer and field strengths in the broadcast band (E layer). All are plotted with respect to days before and after bright aurorae.

We have recently made a study of our last 10 years of recordings of field strengths from WBBM Chicago as received in the vicinity of Boston for days immediately preceding and following conspicuous auroral displays. Comparisons have also been made of the index of sunspottedness for the same intervals. It was immediately apparent from our statistical analysis that on the average auroral displays

followed by 1 day the highest value of sunspottedness, and that on the average 1 to 2 days after the auroral displays occurred, the weakest field strengths on the 770 kc. frequency were recorded. Since waves in the broadcast band are returned from the E layer of the ionosphere, it would appear that there is a definite lag of from 24 to 48 hours between the disturbances in the auroral zone and the greatest deterioration (ionization) in the E layer. Had we similar measurements of field strengths at higher frequencies representing waves returning from the F layer, we might expect a similar effect to occur at an interval intermediate between the time of maximum auroral display and the time of minimum field strengths from the E layer. Such field-strength measurements are not available, but fortunately through the courtesy of the Bell Telephone Laboratories we had available a record of their

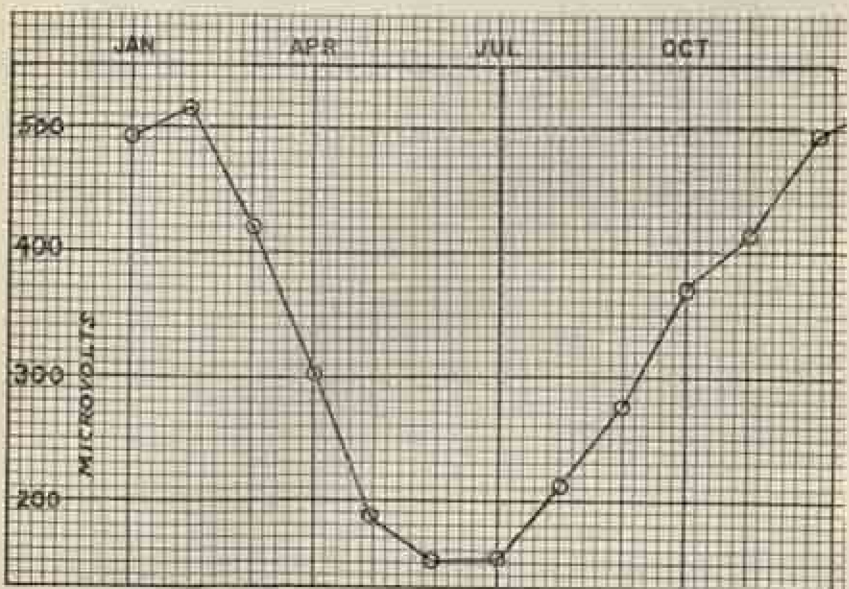

FIGURE 6.—Seasonal trend of radio field strengths (night) of WBBM (770 kc.) as received at Boston. Values here represented are not corrected for twilight effect, which depends upon angle of depression of the sun below the horizon during periods of observation.

transmission disturbances over oceanic paths. Taking the reciprocal of these transmission-disturbance numbers, we have an index of transmission conditions comparable to the field-strength measurements in the broadcast band. A plot of these transmission disturbances for reception from the F layer indicated a lag of roughly 12 hours after the auroral displays for the minimum transmission conditions. This provides perhaps as clear a confirmation as could have been anticipated for ionization disturbances occurring more promptly in the F layer than

in the E layer. The curve of magnetic disturbance in the earth's field parallels very closely that of transmission disturbances in the F layer.

In utilizing field-strength measurements for comparison with cosmic phenomena it has been necessary to apply corrections for the well-known diurnal and seasonal variations which depend upon the extent to which the ionosphere has been illuminated by sunlight during the preceding day. If such correction is not applied, we have of course a

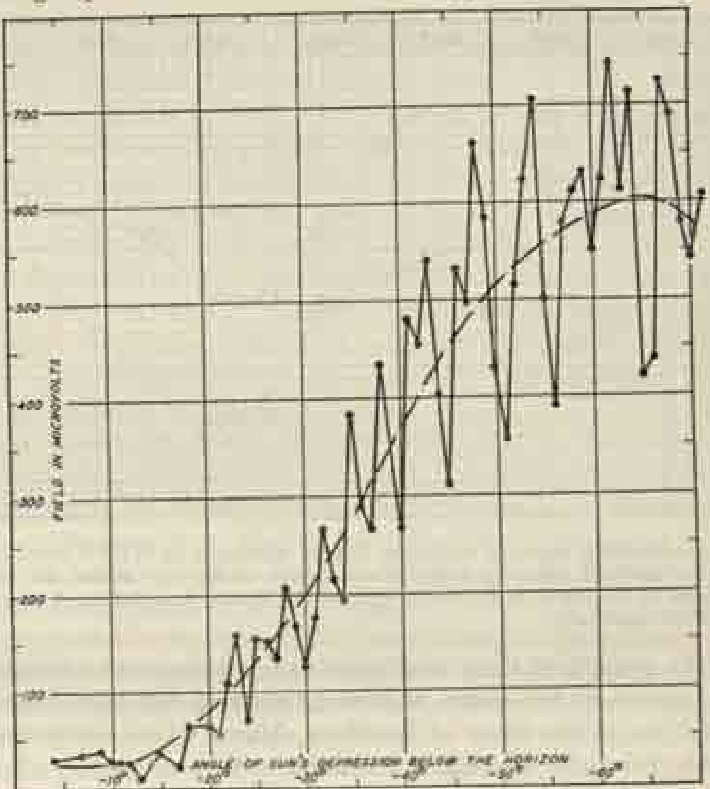

FIGURE 7.—Curve showing gain of nightly field strengths with the increasing depression of the sun below the horizon based on upward of 8,000 hours of observation. The smoothed curve is used as a correction curve for eliminating seasonal trend before comparing radio field strengths with other cosmic phenomena.

marked seasonal trend with a minimum of reception conditions in summer and a maximum in winter. The appropriate correction curve has been derived from over 8,000 half-hourly periods of observations, covering a range of →5° to −70° in the angular depression of the sun below the horizon during the observational periods utilized.

The possibility that an annual or seasonal change exists that is not allowed for by the changing declination of the sun led to the reexamination of all our data of the last few years with the result that a residual annual change apparently exists with a maximum in April and

May and a minimum in September and October. The curve of this residual annual variation strikingly parallels the annual change in the distribution of ozone in northern latitudes as derived by Dobson. The parallelism of these two curves suggests that possibly the cause of the change in the ozone distribution is intimately associated with that of the changes in the ionosphere resulting in this variation in field strengths.

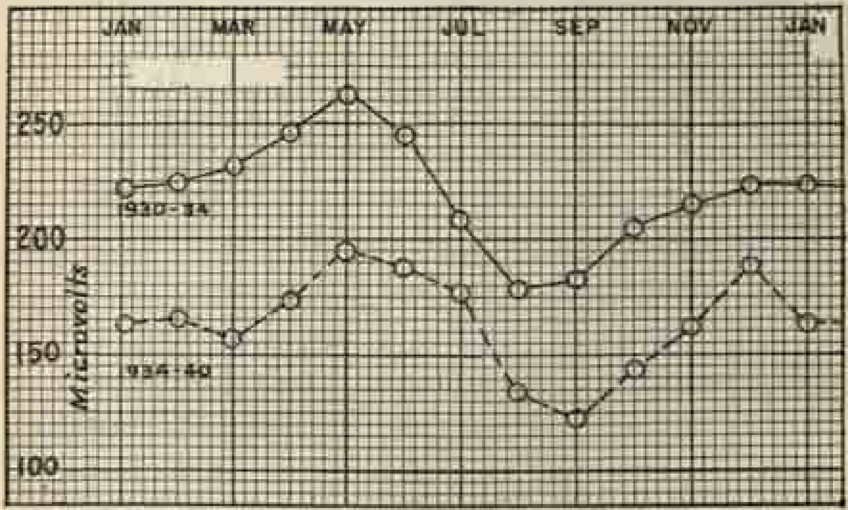

FIGURE 8.—Residual seasonal variation in field strengths of WBBM after corrections for twilight effect or angle of depression of the sun below the horizon. The form of the curve is similar to that of the seasonal variation of ozone content of the upper air.

For the pursuit of these studies in cosmic terrestrial relationships a new laboratory for cosmic terrestrial research has been located in the outskirts of the town of Needham, Mass., where conditions are favorable for radio propagation studies with a minimum of interference, and for observations of atmospheric electric phenomena away from the contamination due to manufacturing in a metropolitan area. The building provides approximately 2,500 square feet of floor space for offices and laboratories. The observational program includes the continuous recording of solar radiation, ultraviolet light, atmospheric potential gradient, ionic content of the lower air and atmospheric electric discharges, as well as the continuation of the measurements of field intensities of radio waves both in the broadcast band and at high frequencies. The relationship of solar observations, ionization phenomena at high altitudes, and radio-wave phenomena to the meteorology of the lower air affords possibilities for extensive investigations which may become of increasing importance.

Attempts to correlate weather changes with solar phenomena have thus far met with varying success. In spite of many conflicting results, it appears that in general the temperature of the world at large is somewhat higher at sunspot minima than at sunspot maxima. This seems at first paradoxical, since we might well expect that at sunspot maxima the sun would send us more heat and radiation than at sunspot minima. Many of Dr. Abbot's observations, especially during the earlier years, seem to corroborate this. Yet the surface temperature of the globe could be actually cooler in years when the earth is receiving more heat from the sun, for increased heat produces increased evaporation which in turn generally results in increased rainfall. Increased rainfall actually lowers the temperature of the earth's surface and again, by evaporation, continues to cool the air immediately above. Furthermore, with the warming of the earth, a vast convectional system of atmospheric currents results. As air warmed near the surface of the earth rises, cold air flows in from the polar regions with its chilling effects. It appears entirely possible that even with an increase in the heat received by the earth from the sun, as far as surface conditions are concerned, actually lower temperatures would occur at selected regions.

As far as changes in the sun's radiation affecting the general circulation of the atmosphere are concerned, it is to be expected that such changes would ultimately give rise to the formation of storms and the storm tracks resulting. One of the difficulties in establishing any intimate connection between weather and sunspots is that our observations of weather tend to be very local.

If progress is to be made, it will come through a consciousness of the distribution of weather as a whole over the entire globe. From a more accurate picture of world weather, indications for weather in a given locality at a given time may be more easily estimated.

Looking at the weather on a world-wide scale, Henry Helm Clayton, of Canton, Mass., has found that pressures oscillate from one region to another in some way which appears to depend upon the intensity of solar activity. He finds there is an opposite trend over the continents and oceans in summer as compared with winter, and that the trend is different in the equatorial regions from that in the extratropical belts. In the equatorial regions temperatures are distinctly lower at sunspot maximum and higher at sunspot minimum. The same is true in the North and South Temperate Zones, but in the arid regions bordering the Tropics, the temperature actually averages a little higher around sunspot maximum than at sunspot minimum. From his studies he concludes that while the North Atlantic shows 10 to 20 percent more precipitation, the eastern half of the United States is in the region where rainfall is actually less during maximum activity on the sun. He concludes that our weather is the

result of certain progressive wavelike movements of certain disturbed areas, orginating in different parts of the world. With each cycle of change in solar activity, the centers of high barometric pressure move from high latitudes to low latitudes and back again. The amplitude of their oscillations and the speed with which these waves progress appears to be inversely proportional to the length of the period of oscillation.

In years of unusually high sunspot maxima, as was the case in 1937, areas of high pressure appear to be pushed farther northward. The return of these highs to low latitudes with accompanying colder and clearer weather may, he believes, be so retarded under such instances as to invert the phase of a cycle that may have persisted for some time while the amplitudes of the oscillations were of less magnitude. Thus there will occur several years when the differences in barometric pressure between the equatorial region and North Temperate Zone become greater than normal, to be followed by several years when the pressure differences become less than normal. The shifting of these centers of action, Clayton believes, is definitely associated with sunspots.

Various attempts have been made to attribute climatic cycles to changes in solar activity. Perhaps the most outstanding scientific contribution in this direction has come from Prof. A. E. Douglass, of the University of Arizona, who has spent a lifetime measuring variations in tree growth, especially in the forests of the Southwest and in California. Douglass noted that sequences in periods of rapid growth of trees, as measured by the widths of their rings, follow very closely the sequences in the sunspot cycle. Since variations in tree growth suggest variations in precipitation, he has accumulated a vast amount of evidence for alternations of wet and dry periods variable with the sunspot cycle, carrying records backward for some 3,000 years. His studies appear to indicate that at least for selected regions, trees have shown most growth when sunspots were most numerous. It does not appear improbable, however, that the growth of trees integrates all favorable conditions and that temperature, the quality of sunlight, and the amount of ultraviolet radiation all enter into the growth rate of trees as well as does rainfall.

Sunspot periods have also been traced with minor discrepancies in the flow of rivers and the level of lakes, some regions responding much more clearly than others to the sunspot cycle.

Altogether we see there are many indications that the earth responds to the changing state of the sun over an interval of a little over 11 years and often by double this period or approximately 23 years. Whether all the effects produced in the earth and its atmosphere that are noticed at sunspot maxima are the result of the sunspots themselves or whether the state of the sun and its whole sur-

roundings are so activated as to change materially the cosmic environment of the earth is a question still unanswered.

In summary, we have reviewed a few of the important ways in which the sun and the atmosphere are closely associated. The solar cycle marked by the coming and going of sunspots appears definitely to be reflected in geomagnetic phenomena of the earth, in the ionization of the upper atmosphere affecting all radio communication, in climatic cycles of the past and in a somewhat complex manner with weather variations today. Perhaps some day terrestrial effects yet to be discovered may in turn become predictable through cycles that follow law and order. Difficult as the pursuit of such investigations may be, results already attained are a stimulus to sustained effort, and we are becoming increasingly conscious withal of a more intimate relationship between the earth and its cosmic environment than could have been suspected a decade or two ago. In this cosmic environment we may be assured the sun will play a major role.

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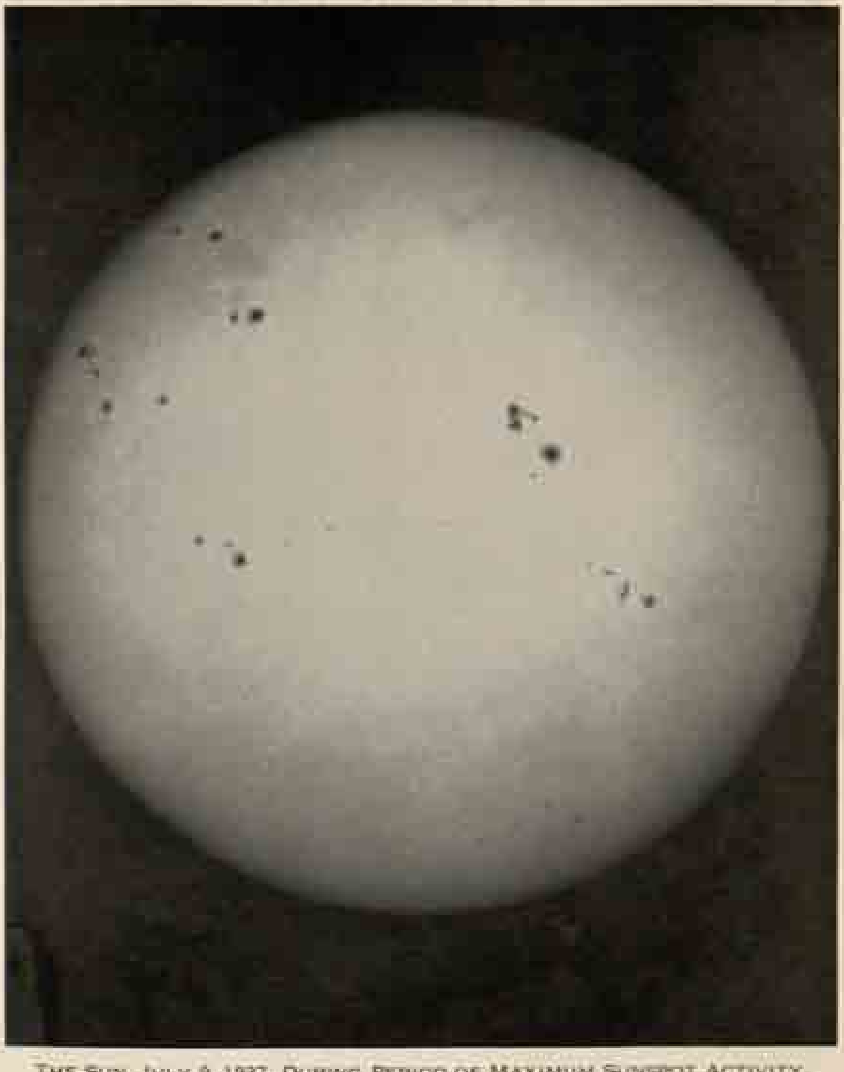
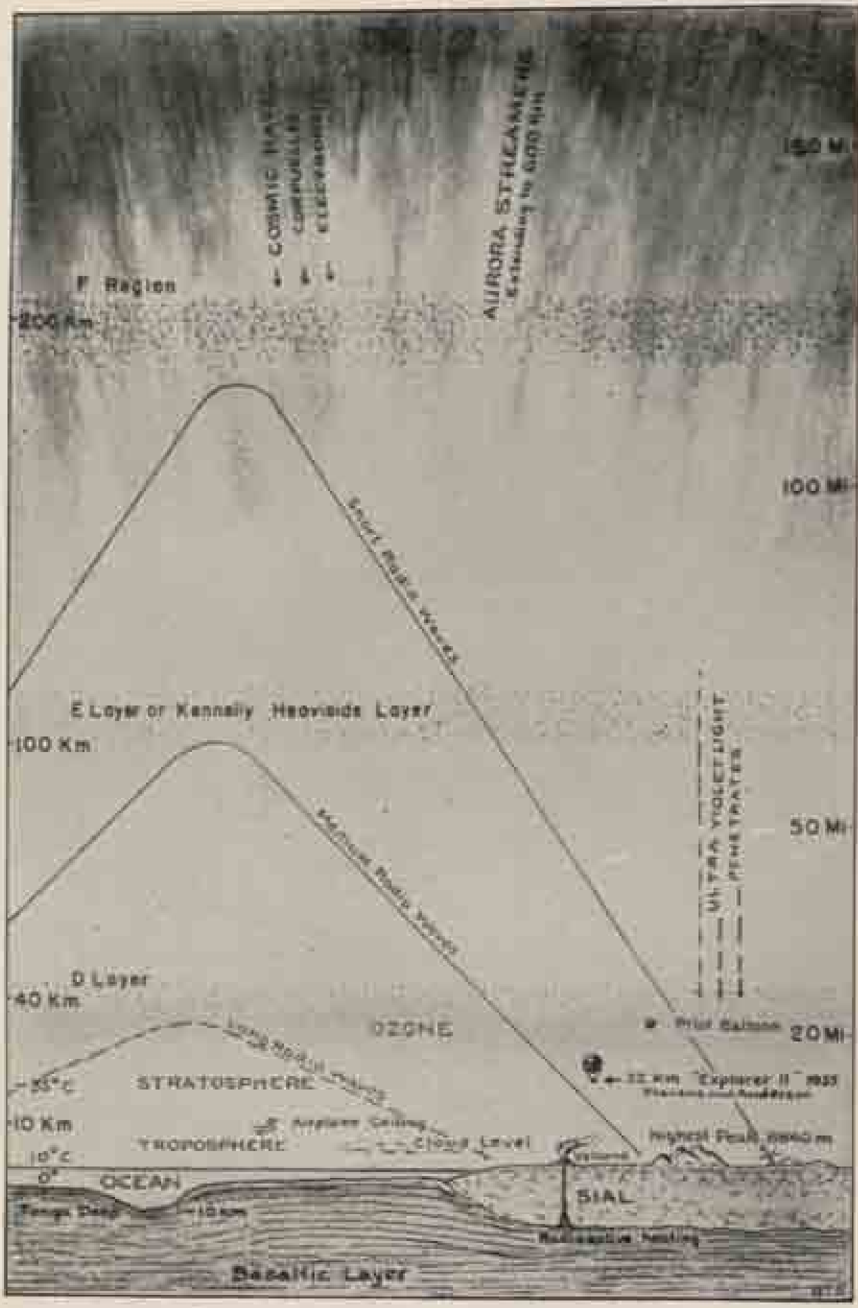


THE SUN, JULY 9, 1937, DURING PERIOD OF MAXIMUM SUNSPOT ACTIVITY.
Photograph by Wm. Keaton.



CROSS SECTION OF EARTH'S ATMOSPHERE.

APPARATUS USED IN RECORDING CONTINUOUS NIGHTLY FIELDS FROM WBBM, CHICAGO, AT NEEDHAM LABORATORY.

NEWLY ESTABLISHED LABORATORY FOR COSMIC TERRESTRIAL RESEARCH IN NEEDHAM, MASS.

The residence of the director is in the background at the right.

THE SUN AND THE EARTH'S MAGNETIC FIELD[1]

By J. A. Fleming
Director, Department of Terrestrial Magnetism, Carnegie Institution of Washington

[With 19 plates]

INTRODUCTION

The Smithsonian Institution has been interested since its foundation in 1846 in researches involving the sun. Its first Secretary, Joseph Henry, was also interested in the earth's magnetism and in 1830-31 made a series of observations at Albany, N. Y., to determine its intensity, and observed and reported upon a magnetic disturbance in connection with the appearance of an aurora. He nurtured the idea that solar investigations might be advanced by the application of laboratory technique. By the use of thermoelectric apparatus in connection with the solar disk projected by a telescope on a screen in a dark room, he concluded that a sunspot emitted less heat than the surrounding parts of the luminous disk. As a member of the faculty of Yale College, he accompanied his friend A. D. Bache—American pioneer in the study of the earth's magnetic field—who went to Europe in 1837-38 to purchase instruments for the first magnetic observatory (Girard College, Philadelphia) and survey in the United States. In one of his memoirs he says, "It must now be admitted that magnetism is not confined to our earth, but is common to other and probably all bodies of our system." Through these researches, coupled with others pertaining to various aspects of solar radiation, Henry foreshadowed the productive researches in solar physics so ably conducted and encouraged for many years by the present Secretary.

We are all acquainted with certain familiar aspects of the sun. We all know that it gives us light and warmth. We have all seen it set in the evening and—since the introduction of war time—many of us have seen it rise in the morning. Biologists have interpreted the physiological effects of the sun's radiation on plants and animals and have shown how the chlorophyll and other substances in vegetable

[1] The eleventh Arthur lecture given under the auspices of the Smithsonian Institution, February 26, 1942.

tissue convert this solar energy into chemical energy and how the sun's rays falling on living animals create vitamins so essential to healthy development. Paleontologists and geologists have shown how the sun's energy has been captured in the past and preserved for us through the ages, even though we are now forced to waste much of that precious energy in the prosecution of the war. There are, in addition, certain effects of the sun's radiation not directly perceptible to our senses but nevertheless of considerable importance to our modern lives. I refer to the great physiochemical action of the sun's radiation on our outer atmosphere. Through this intervening medium the sun affects the earth's magnetism, produces polar lights, and makes possible transmission of radio messages over great distances. Through study of these effects we are able in turn to obtain a better understanding of solar phenomena. In particular, we have learned that the sun not only sends out wave radiation but particle radiation as well, and that the intensity of ultraviolet radiation from the sun far exceeds what should be expected from observations of its visible radiation alone. Our subject is this aspect of the sun and its manifold consequences on the earth.

SOLAR PHENOMENA[3]

The sun is an ever-changing, seething sphere 864,300 miles in diameter. When viewed through a telescope, its surface appears granular; this is because of small variations in temperature over relatively small areas (a few hundred square miles). Most obvious of solar surface disturbances are the very large dark areas—in reality luminous, but dark by contrast—known as sunspots, which frequently appear. These vary greatly in size and on rare occasions may be almost 20 earth-diameters across. A spot about 30,000 miles or 2 earth-diameters across can be seen with the eye through a piece of smoked glass. Its day-to-day motion shows that the sun rotates in the same direction as the earth. Sunspots tend also to occur in pairs, though having smaller companions, with the larger or more stable spot in the direction of the sun's rotation from left to right as seen from the earth. They are solar tornadoes in which the whirling gases show features resembling the field of an electromagnet. The great flames called prominences, seen more readily near the edge of the sun, may remain relatively steady for several days, occasionally in form of arches. Eruptive prominences, attaining heights of hundreds of thousands of miles, may appear in rapid succession, in arched form, above an area subsequently occupied by sunspots. The following motion of the gas

[3] The author is indebted to members of the staff of the Mount Wilson Observatory, especially to Director W. S. Adams and to Drs. Seth B. Nicholson and R. S. Richardson, from whose articles much of the matter in this section on solar phenomena is taken, and for permission to reproduce some of the Observatory's beautiful solar photographs.

clouds escaping into surrounding space is not readily traced because of the rarefaction and decreased luminosity of the gas.

The areas involved in these rapidly changing granulations, sunspots, and the long bright streaks or faculae, usually branched, and other phenomena accompanying sunspots are so small as contrasted with the whole area of the sun that the direct effect of their variations is rarely more than a fraction of 1 percent of the total solar radiation. Thus these phenomena must be indices of some more fundamental solar change rather than direct factors causing any large measurable changes in the amount of solar radiation—as will appear later in the discussion of their effects on the magnetic field of the earth.

The unsettled and troubled conditions on the sun extend outward for vast distances into adjacent space. The brightly illuminated gaseous material forms the beautiful solar corona, formerly observable only during eclipses but now photographed at times other than eclipses by means of special optical instruments designed some years ago by the French scientist Lyot at Pic du Midi. The coronal envelope varies in a marked way with variation in frequency of sunspots. The streamers and plumes near the poles of the sun suggest in shape the lines of force of a spherical magnet, and near the equator sometimes extend outward many solar diameters.

In 1908 Hale, at the Mount Wilson Observatory, showed that sunspots have intense magnetic fields, which for large sunspots may be of intensity 3,000 to 4,000 gausses or more—comparable to those between the pole pieces of large dynamos. Small spots 200 to 300 miles in diameter have field strengths about one-thirtieth as great. In general, the field strength at the center of a spot is roughly proportional to the logarithm of the radius of the dark and cooler central part or umbra and diminishes toward zero at the outer and lighter part or penumbra. The discovery of these magnetic fields was made through study of characteristic features of spectra of sunspots utilizing the Zeeman effect which reveals that when light is passed through a strong magnetic field each single spectral line is turned into a doublet or triplet—the doublet when the light is viewed in the direction of the lines of magnetic force and the triplet when viewed in the perpendicular direction. The strength of the magnetic field is determined from the differences in the wave lengths of the separate components. These observations show that the lines of force are normal to the surface at the umbra of a spot but that toward the penumbra they spread outward.

Many sunspots are surrounded by hydrogen vortices as shown by photographs of the sun's surface by the light of hot hydrogen or calcium. From these photographs, estimates are made of the great rapidity of vortical motion. The direction of rotation of these vortices is generally counterclockwise in the northern hemisphere and

clockwise in the southern. The direction of the vortical rotation is associated with the direction of the magnetic field of a spot; two spots for which vortical motion is opposite have oppositely directed magnetic fields.

For routine observation of magnetic fields and sunspots a special analyzer is used by which one determines the magnetic polarity of a sunspot, observing merely whether the positive (red) or the negative (violet) component of a line is transmitted.

Sunspots usually appear in elongated groups, and spots at opposite ends of these groups have opposite polarities. Although it was soon realized that the number of sunspots varied with time, it was not until 1843 that Schwabe showed that they occurred in cycles. From the results since then of many years of observation by devoted observers in all parts of the world, the spottedness of the sun has been found to vary in a somewhat irregular fashion with an average period of about 11 years. This 11-year cycle does not progress smoothly but in short-period pulsations which vary in length from about 15 months to periods as short as 5 or 6 months. The polarities of spots in a new cycle are opposite to those after the minimum of the preceding cycle. The spots at the first of a new cycle are in zones about 30° from the equator; they gradually approach the solar equator at the end of the cycle. Thus solar activity apparently has a fundamental cycle double that of the 11-year cycle. The fact that spots have been more numerous in alternate 11-year cycles also indicates this. From the viewpoint of effects on the earth, the 11-year period is probably more important. All spots appear to move across the sun's disk from east to west. Many single spots and groups of spots, which have passed from sight around the sun's western edge, have been recognized on their reappearance, after about 2 weeks' time, at the eastern edge.

It has been concluded from the recurrences of such groups that the period of the sun's rotation is about 27 days. To be more precise, the interval elapsing between two successive passages of a spot across the sun's central line is a little less than 27 days for spots on the sun's equator and this interval increases to more than 28 days for those midway between the equator and the poles. Spots are rarely observed any nearer to the sun's poles. The outlines of sunspots are variable; some do not reappear at all and others exist through several rotations, but rarely persist for longer than half a year. They do not endure as do the surface irregularities on the earth and moon.

Observations by the spectroscopic method have shown that the sun also has a general magnetic field somewhat like that of the earth with opposite poles of unchanging polarity in the northern and southern hemispheres. However, the field intensity is small and unusual care is required to detect it. The measurements made at the Mount Wilson Observatory indicate that the north magnetic pole of the sun is

about 4° from its pole and thus much nearer than is the case for the earth whose magnetic axis makes an angle of 11.°5 with the axis of rotation. From variation in the inclination of the magnetic axis of the sun as the sun rotates, it appears that the magnetic pole rotates about the geographical pole once in about 31½ days. The sun's magnetic field is about 50 gausses or 100 times greater at its surface than the maximum value of the magnetic field of the earth and its intensity decreases rapidly with height.

Exceedingly brilliant clouds occasionally burst forth suddenly on the sun and reach maximum brightness in a few minutes and then slowly subside. These spectacular bright eruptions usually last from 10 to 30 minutes, depending upon their brightness, although some of the most brilliant have remained as long as a few hours. They usually occur in the neighborhood of magnetically complex—usually also abnormally active—sunspots, which change rapidly in form and size. They flare up into the solar atmosphere far above the level of the sunspots like sheets or tongues of flame extending outward; often, brilliant fountainlike prominences are observed over such active spot groups. The upper region of the solar atmosphere where these clouds appear is called the chromosphere, and in it are also the many other fainter and more stable prominences. Although the latter are much fainter, they usually extend higher above the solar surface than the very bright clouds that appear so suddenly. Because of their brightness and almost explosive nature, these active prominences are called chromospheric eruptions to distinguish them from less intense eruptions. Spectroscopic analysis of the light from the chromospheric eruptions shows that they are composed mainly of hydrogen and helium.

It has been found that chromospheric eruptions produce terrestrial effects throughout the daylight hemisphere on the earth. The visible radiations of these bright eruptions cannot account for the observed results on the earth, indicating that an immense increase in the invisible or ultraviolet light must accompany them. These eruptions, with their direct almost simultaneous effects on the earth furnish the first and only evidence which has so far been obtained of positive terrestrial changes produced by specific solar phenomena and have opened the way to the solution of many problems of influences of solar activity on the earth's magnetism.

THE EARTH'S MAGNETIC FIELD

The complex nature of geomagnetism—the general magnetic field of the earth—and of its varied phenomena is still a riddle. Despite several centuries of speculation and research, there is as yet no adequate explanation of how the earth became magnetic or why it remains so. Associated with this problem is the "perpetual vari-

ability" of geomagnetism at any one place—changes, on the one hand, slow when compared with the life span of the individual, as in its long-time or secular change, and, on the other hand, rapid, as in its short-time or more ephemeral changes; it is largely in the latter that we find interrelations with cosmical phenomena in space about us.

The compass appears simple though mysterious in its directive ability which demonstrates that magnetic forces are present everywhere about us. This is evidenced also by the inductive magnetic action of the earth's field upon a material highly susceptible to such action, for example, an alloy such as permalloy with unusually great capacity for transient induced magnetization in weak magnetic fields like that of our planet. When a thin long rod of permalloy

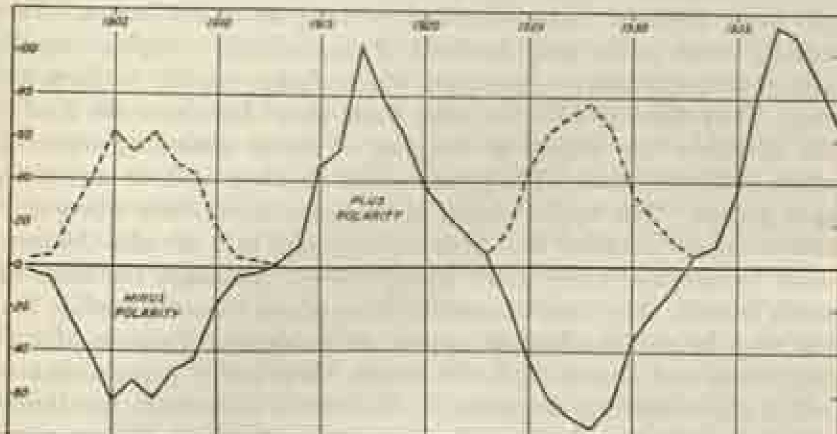


FIGURE 1.—Sunspot numbers and cycles of plus and minus polarities, 1900-1940. (After S. B. Nicholson.)

is directed toward the north magnetic pole of the earth, the magnetization induced in the bar by the geomagnetic field is quite sufficient to lift small pieces of permalloy. But as the rod is turned with its length at right angles to the field and thus in the direction least favorable to induction, it loses the magnetism induced by the earth and will no longer support such metal strips, which fall. But that which is apparently simple is often the most baffling as in this case, perhaps not in the physical principles concerned, yet certainly in the origin and observed periodic and aperiodic fluctuations of the forces involved.

The first perception of the natural phenomena of geomagnetism through the directive property of a lodestone or magnet freely suspended in the earth's field is veiled by the myths and legends of south-pointing chariots in China some 4,500 years ago and of its applications by the Egyptians, the Phoenicians, the Greeks, and the Latins. However, there is definite and well-authenticated evidence

of the use of this property in navigation by the end of the twelfth century A. D.

Magnetic dip or inclination was unknown until 1581, when Robert Norman of London, a practical seaman and instrument maker, published "The newe Attractive, containyng a short discourse of the Magnes or Lodestone, and amongest other his vertues, of a newe discouered secret and subtill propertie, concernyng the Declinyng of the Needle, touched therewith under the plaine of the Horizon."[8] Norman mounted his needle on a horizontal axle so that it was free to move in the vertical plane and observed the actual dipping below the horizon. This gave the first hint that the source of the magnetic field of the earth might be within the globe and not in the stars as previously supposed.

Thence onward there was gradual transition from the field of speculation to that of scientific investigation, and in 1600 Gilbert published his famous book on the magnet, the first treatise picturing the earth's action as a great magnet, a conclusion which preceded Newton's announcement of universal gravitation. A century later Halley's world charts showing "variations"—that is, declination—of the compass appeared. Wilcke's chart of magnetic dip or inclination was published in 1768. Charts delineating magnetic directive force resulted from Humboldt's observations on his American journeys during 1799 to 1803.

The period including the end of the eighteenth century and the first half of the nineteenth century was an era of unequaled constructive work in geomagnetism by many eminent scholars. Among these may be mentioned Humboldt, Gauss, and Lamont of Germany, Sabine and Airy of Great Britain, Poisson and Duperrey of France, Quetelet of Belgium, Hansteen of Norway, Kupffer of Russia, and Nicollet, Locke, Loomis, Bache, and Henry of America.

That thoughts on this subject were then not limited to scientific men is evidenced by a discourse of John Quincy Adams in our House of Representatives during preliminary steps bearing on the establishment of the Smithsonian Institution in which he said:

> What an unknown world of mind is yet . . . to be revealed in tracing the causes of the sympathy between the magnet and the pole—that unseen, immaterial spirit, which walks with us through the most entangled forests, over the most interminable wilderness, and across every region of the pathless deep, by day, by night . . . Who can witness the movements of that tremulous needle, poised upon its center, still tending to the polar star, without feeling a thrill of amazement approaching to superstition?

[8] In 1544 Georg Hartmann of Nuremburg stated he had noticed that a magnet not only declines from the north and turns toward the east but also points downward. Hartmann, however, did not mount his needle in such a manner as to show the precise amount of dip, as did Norman.

The picture of magnetic phenomena is incomplete if viewed only in a man-made laboratory, even though we can now produce there an artificial magnetic field within a space of a cubic inch which is 100,000 and more times as intense as that of the earth. Fortunately, Nature provides not only the earth and its atmosphere as a great magnetic laboratory but also continuously performs experiments, utilizing as apparatus the sun, the moon, and the radiations from space. The interpretation of observable data in so vast a laboratory requires special types of research and, in unique degree, world-wide coordination of data and experiment. No single well-planned experiment or observation can solve the problems presented. Observations must be made in all parts of the world and must be continued over a long period. Techniques for the organization and interpretation of these data must be developed and experimental researches must be conducted along lines which will supply information on basic properties related to the subject. Thus it is only through mutual assistance and cooperation of investigators in geophysics, in geology, in astronomy, in physics, and in mathematics that we may hope to forward interpretation of natural phenomena. Progress in the earth sciences is not the result of individual research; it proceeds not from the isolated work of the few, but from the coordinated efforts of the many. Truly, some individuals may contribute more than others to this evolution of understanding, but their power to contribute is to a large extent determined by the works of their predecessors and of their colleagues.

The geomagnetic field extends far out into the atmosphere and beyond it. Even 4,000 miles above us it is still one-eighth as great as at the earth's surface. Our globe may be regarded as approximately a uniformly magnetized sphere with its axis making an angle of 11.°5 with the axis of rotation. Although but feebly magnetized as compared with the magnetization attainable in high-grade magnet steels, the average intensity of magnetization is many orders of magnitude greater than that observed in ordinary crustal rocks. Appreciable irregularities in the field exist, but they do not cause great departures from the field which would be produced by the hypothetical uniform magnetization. The moments of the uniform portion of the earth's magnetism, the axial, and the equatorial components in centimeter-gram-second units, as determined by Bauer's analysis of available data in 1923, are $M=8.04\times10^{25}$, $M_a=7.88\times10^{25}$, and $M_e=1.60\times10^{25}$, respectively. If the magnetism were distributed uniformly throughout the earth's volume, the average intensity of magnetization would be 0.074 centimeter-gram-second unit. A general idea of the field may be obtained by the distribution of iron filings over a disk magnet, but in reality the earth's field is much more complicated.

The principal magnetic poles are distant 1,200 miles or more from the geographic poles. The north magnetic pole, visited in 1831 by Ross and in 1903 by Amundsen, is in Boothia Peninsula in north Canada (latitude 70.°5 north, longitude 95.°5 west). The south magnetic pole, reached in 1909 by E. David, Douglas Mawson, and A. Mackay, of Shackleton's British Antarctic Expedition of 1907–09, is in South Victoria Land of the Antarctic Continent (latitude 72.°4 south, longitude 155.°3 east). Thus the line joining the magnetic poles is not a diameter of the earth but passes at a distance of some 750 miles from its center. It is to be noted that the equivalent axis of the uniform magnetization intercepts the northern hemisphere in latitude 78.°5 north and longitude 69.°1 west. Thus these so-called "geomagnetic" poles are considerably removed from the actual magnetic poles as observed.

Measurements to determine the earth's magnetic field at any point and time must include observations of three magnetic elements, namely: (1) Magnetic declination or direction, the angle between the true astronomical north-south meridional plane and the vertical plane through the magnetic north-south direction as defined by the compass; (2) magnetic inclination or dip, the angle through which a magnet entirely free to move would dip below the horizon in the magnetic north-south meridional plane; and (3) the total magnetic force, acting in the magnetic meridional plane or its horizontal component or its vertical component.

Painstaking and patient recording and analyses of the complex geomagnetic variations through days, years, and decades at observatories and on magnetic surveys on land and sea have disclosed certain systematic features and irregular variations of these, all of which may be designated as time changes of the geomagnetic field. The more pronounced systematic and periodic features are the secular, daily or solar diurnal, lunar-day, and annual variations.

Secular variation is a progressive change, that is, a slow age-long variation; it was first noted in compass direction—the so-called variation of the mariner—by Gellibrand in 1634 who announced quaintly that "variation is accompanied with a variation." It takes important part in navigation at sea by magnetic direction as indicated by the compass—a use which stimulated and maintained interest in determining its value from the time of Columbus. Before the invention of chronometers it was thought that geographic position might be derived from knowledge of changes from place to place in magnetic declination and inclination. This led to the first systematic oceanic survey by the astronomer Edmund Halley in the Atlantic Ocean during 1698–1700 on the pink[4] *Paramour.* Halley's was the first

[4] A pink is an old-style, narrow-sterned sailing vessel.

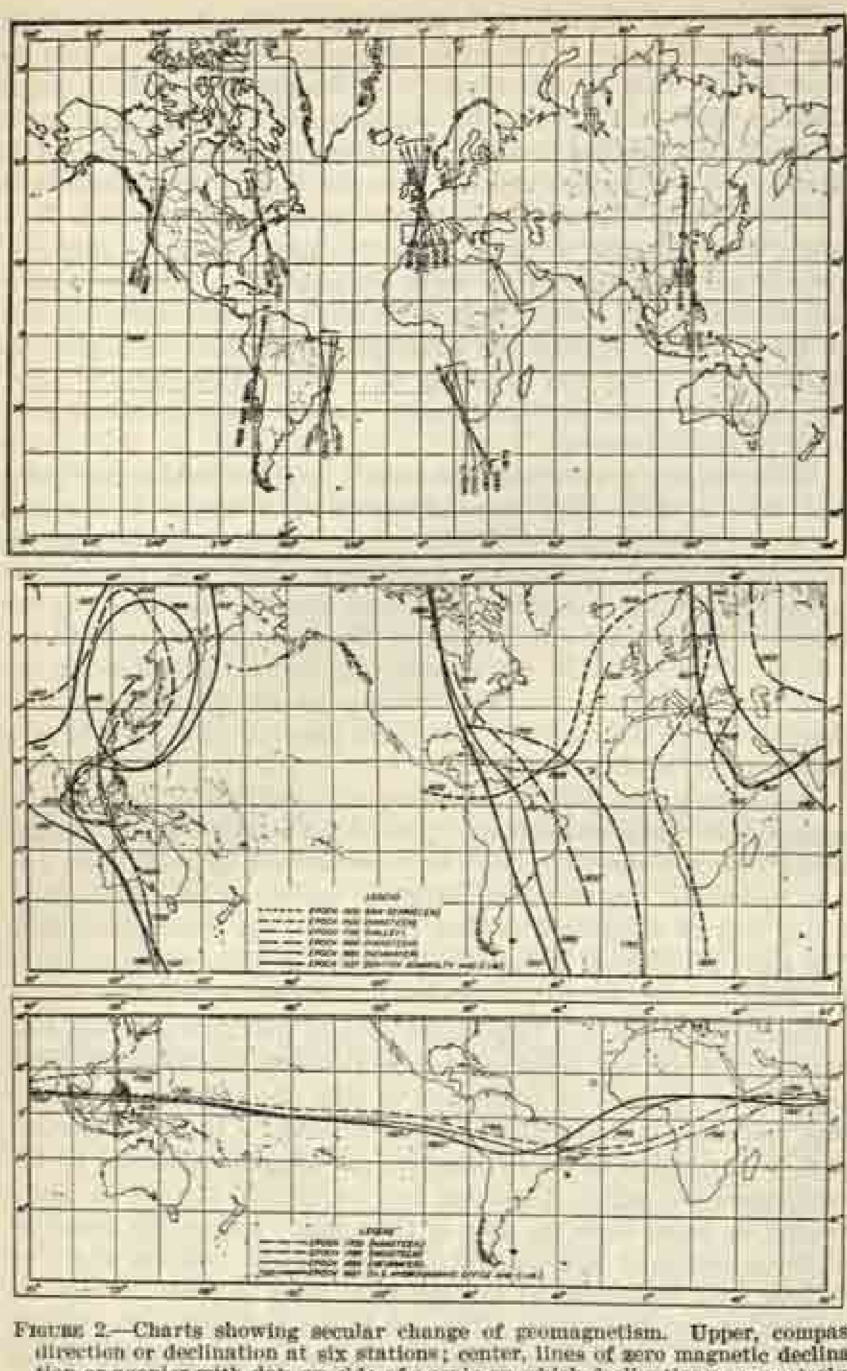


FIGURE 2.—Charts showing secular change of geomagnetism. Upper, compass direction or declination at six stations; center, lines of zero magnetic declination or agonics with dots on side of agonic on which declinations are easterly; lower, lines of zero magnetic inclination or isoclinics.

chart to show lines along which the compass direction differed from the true north by the same angle, that is, lines of equal magnetic declination or isogonics. Corresponding isoclinic and isodynamic charts show lines of equal dipping or inclination and of equal horizontal, vertical, or total magnetic force acting on the compass. World charts of these magnetic contours for different epochs show marked changes in their trends—changes caused by secular variation. Secular variations show apparent small-order dependence in their progress on the sunspot cycle.

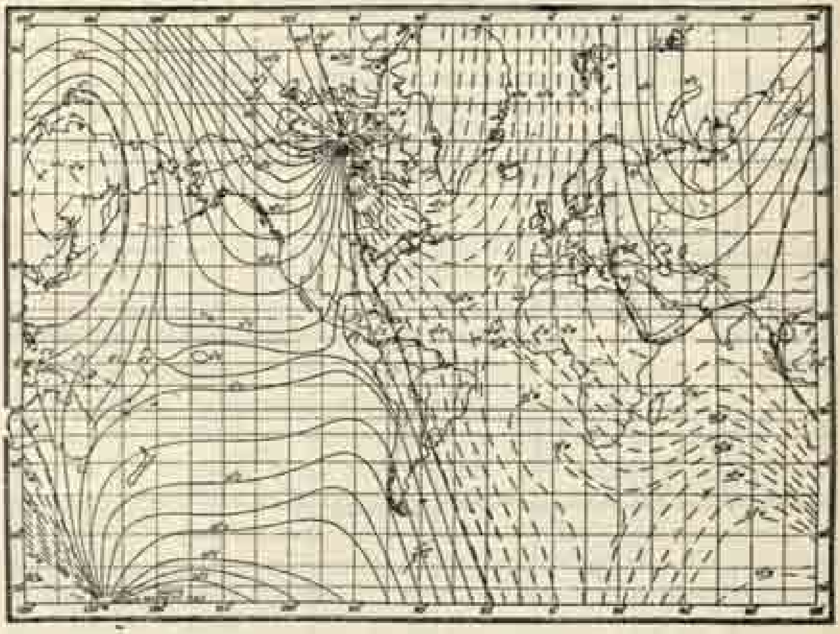


FIGURE 3.—Isomagnetic chart of lines of equal declination or isogonics, epoch 1930. (After U. S. Hydrographic Office.)

The second important time change is the 24-hour daily or solar variation. This variation takes place chiefly during daylight and changes in a more or less regular manner in magnitude and character with geographic position, with the seasons of the year, and with solar cycles; it was first observed [a] and defined in 1722. It is repeated from day to day and is most clearly seen on records obtained on magnetically quiet days. As dawn approaches each day the north end of every compass needle in the Northern Hemisphere shifts slightly toward the east, attaining a maximum eastward elongation

[a] Experiments in the presence of the King at Louveau, Thailand, in 1682 showed the compass direction to be different on seven different days; probably these were made at different times of day and thus were really the first observed indications of diurnal variation.

from its average about 7 to 8 o'clock, then shifts westwardly passing its average daily direction shortly before noon, reaches an extreme eastward position about 1 or 2 o'clock, and during the late afternoon hours begins to shift eastwardly back to the average direction which it maintains practically during the night hours. In the Southern Hemisphere the motion is reversed, the south end of the compass needle exhibiting the same tendency to follow the sun's apparent motion. Toward the North and the South Poles the diurnal variation is greatest, while near the Equator it is practically zero. Somewhat similar behavior during the day and night is shown also by the other magnetic elements.

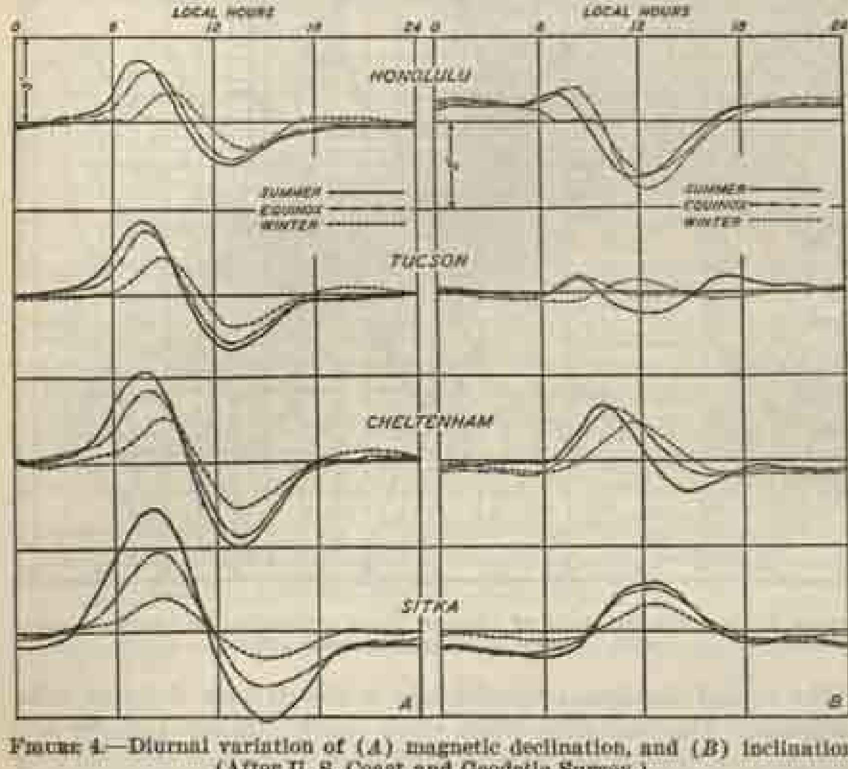


FIGURE 4.—Diurnal variation of (*A*) magnetic declination, and (*B*) inclination. (After U. S. Coast and Geodetic Survey.)

Thus it is apparent that in its main features the solar diurnal variation progresses according to local mean time. Therefore, this variation is connected with the earth's rotation and, as its major tendency follows the apparent motion of the sun, it may be presumed that the sun is an important factor in this daily phenomenon. This is an indication that the earth's magnetism responds to outside influences which find their origin in solar activity and act upon the upper regions of the atmosphere.

The lunar-day variation, while averaging less than one-tenth that of the solar day, is quite systematic. Instead of considering the

changes hour to hour from midnight to midnight, that is, from one lower transit of the sun to the next, the data are studied for 24 lunar hours, that is, for the lunar day from one lower transit of the moon to the next—an average of 23 hours 10 minutes for 24 lunar hours. While this variation is too small to have practical interest in navigation, it is very important for the investigation of the high layers of the atmosphere. The double wave of the lunar variation indicates its tidal origin. It is likely that the lunar variations originate in even higher layers of the atmosphere than the solar variations, because they are so extremely sensitive to changes in magnetic activity. These geomagnetic tides provide a new approach to the study of resonance phenomena in atmospheric oscillations.

The minute annual variation is revealed when monthly values of the magnetic elements are corrected for progressive secular change. It should not be confused with the annual change which is the change in one year due to secular variation.

There are other magnetic time changes of quasi-regular and of irregular type. The more important of these in relation to the sun are short-period, long-period, and sudden-commencement disturbances superimposed on the systematic variations and designated as magnetic storms and perturbations.

These are associated with what we call the earth's magnetic activity or, let us say, its general state of magnetic rest or magnetic unrest, and herein we find spectacular features emphasizing apparent relations to the observed solar phenomena. The magnetic activity at a given station, during any interval, may be defined as a measure for the frequency and intensity of marked irregular departures from the normal diurnal variation in that interval. There are several ways of applying such a definition. The simplest is that in which every observatory, from inspection of its photographic records, assigns to each 24 hours between successive Greenwich midnights a "character figure," designated as C, on a scale of 0–1–2. The character "0" applies to quiet, "1" to moderately disturbed, and "2" to greatly disturbed days. From these the International Association of Terrestrial Magnetism and Electricity also determines the five least disturbed and the five most disturbed days in each month and selects certain days for reproduction in the annual publication of magnetic results from each observatory. This measure, maintained by international agreement since 1906, gives adopted average daily values for all collaborating observatories—now numbering nearly 60.

A more detailed measure is that depending upon the day-to-day changes in the mean values of the horizontal component of the magnetic force since magnetic disturbances have a systematic effect on that component. This effect is an initial rise, followed by a larger decrease accompanied by more or less violent perturbations, and a

slow recovery. The activity is smallest at the earth's magnetic equator and increases in a regular manner to its greatest value in the auroral zone. This daily figure of activity, known as the *u* measure, is roughly defined as the average change from day to day, regardless

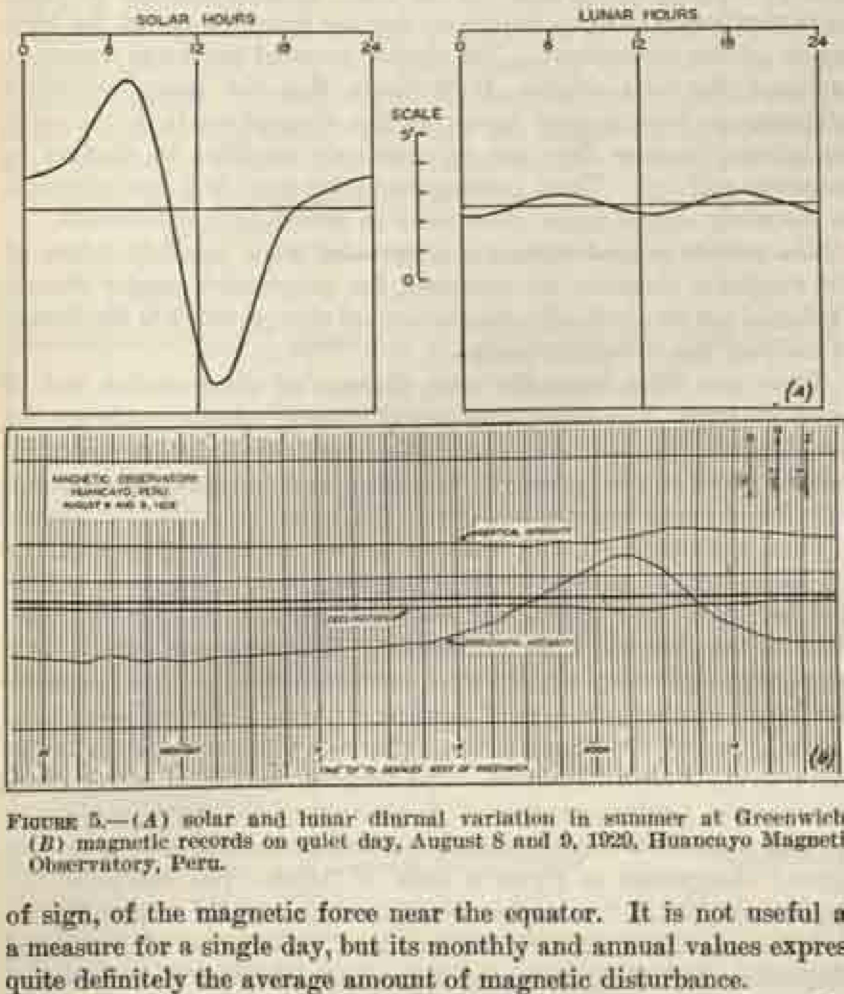


FIGURE 5.—(*A*) solar and lunar diurnal variation in summer at Greenwich; (*B*) magnetic records on quiet day, August 8 and 9, 1929, Huancayo Magnetic Observatory, Peru.

of sign, of the magnetic force near the equator. It is not useful as a measure for a single day, but its monthly and annual values express quite definitely the average amount of magnetic disturbance.

A certain lag of *u* behind the sunspots supports the theory that when sunspots are nearer the sun's equator there is greater probability that the corpuscles, emitted more or less radially from the sun, are more likely to sweep across the earth.

Developments in the science of geomagnetism and correlative effects with other geophysical phenomena, especially those concerned with radio communication, have made desirable a quantitative and more detailed measure of geomagnetic activity. This measure is the 3-hour range index, *K*, which evaluates geomagnetic activity

for each of the eight 3-hour periods of the Greenwich day. The activity in excess of the regular daily variation is measured for each 3-hour period and an index from 0 to 9 is assigned in accordance with the activity "0" for very quiet and "9" for extremely disturbed. Thus, by means of eight indices, the geomagnetic activity for a day is abstracted from the continuous magnetic records at each observatory. The progress of a magnetic storm is readily followed and the geomagnetic activity at one observatory may be compared with that at another observatory in a different geomagnetic latitude; for example, the K indices for the period 09^h to 12^h, February 5, 1942, at observatories arranged in order of increasing north geomagnetic latitude Φ were 3, 3, 5, 5, 6, and 7 at Honolulu ($\Phi = 21°$), San Juan ($\Phi = 30°$), Tucson ($\Phi = 40°$), Cheltenham ($\Phi = 50°$), Sitka ($\Phi = 60°$), and College ($\Phi = 64°$). For the same period the index at Watheroo at 42° south geomagnetic latitude was 4.

Violent magnetic storms with 3-hour-range index of 9 occur only a few times near a sunspot maximum, but it is equally rare that any full 3-hour interval is perfectly free from disturbance. This means that the earth is almost constantly, even near sunspot minimum, under the influence of particles (presumably solar), weak as this influence may be at times.

The intensity of the ionizing solar wave radiation absorbed in the ionosphere on the daylight hemisphere can likewise be measured geomagnetically in the amplitudes of the solar daily magnetic variation. Analysis of 18 years' records (1922–39) of horizontal intensity at the Huancayo Magnetic Observatory, in which the magnitude of the solar daily magnetic variation is exceptional, gave a measure for the ionizing solar wave radiation comparable with the relative sunspot numbers as the only available complete series of daily measures of solar activity. The correlation coefficient between them is +0.92 for monthly means and +0.984 for annual means. These are the closest relations so far established between phenomena on the sun and the earth.

From the indices supplied by individual observatories, a mean index may be derived which will represent world-wide conditions. The mean indices computed from the data supplied by seven American-operated observatories during the year 1941 show three outstanding storms in 1941 on March 1, July 5, and September 18 and 19. A remarkable recurrence of quiet conditions also occurred during the year. January 5 was the first quiet day of this series followed by 13 quiet-day recurrences at exactly 27-day intervals.

Magnetic disturbances may be classified as (1) world-wide magnetic storms, simultaneous over the earth and primarily due to changes in the electric conditions outside the earth, and (2) smaller disturbances restricted to parts of the globe and with center of field

of action at times stationary but generally moving from place to place. Storms of the first type may follow comparatively quiet or normal conditions and are often initiated by a sudden sharp shift—a "sudden commencement"—simultaneous, within a minute of time, at all observatories. A tendency to oscillation and continued unrest during intervals varying from 10 hours to several days is one of the outstanding features of such storms.

The second, more local, type of transient magnetic disturbances is usually represented by a rather slowly developing "bay" on the record extending over half an hour or somewhat more.

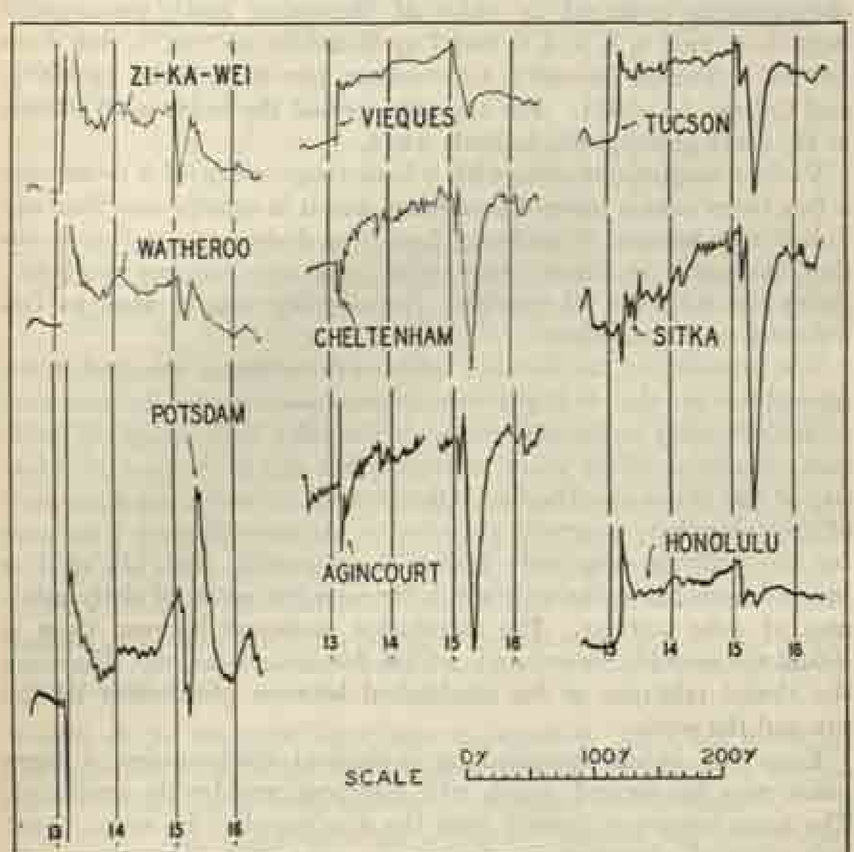


FIGURE 6.—World-wide sudden commencement of geomagnetic storm at 13h09m, Greenwich mean time, May 13, 1921, showing changes in horizontal-intensity component.

Thus disturbed or quiet magnetic conditions nearly always affect the whole earth simultaneously. The possibility of any connection between the disturbances of the earth's magnetic field and the weather is excluded since weather is so distinctly local and so different all over the world. But polar lights—the auroras—are always seen in polar regions when magnetic storms occur. In 1741 Celsius and

Hiörter at Upsala confirmed, by a long series of observations, the connection between auroral displays and disturbances in the normal fluctuations of the needle. To explain these spectacular displays, which appear as curtains, arches, bands, and rays, with many variations, extensive mathematical and experimental investigations have been made, especially by our Norwegian colleagues. Birkeland, by means of a cathode sphere in a vacuum chamber, demonstrated the accumulation of electrons in the plane of the magnetic equator. Since that time his distinguished successors, Störmer and Vegard, have done much to advance the study of auroral phenomena. Elaborate calculations of the paths of electrified corpuscles which are entrapped between outermost lines of magnetic force of the earth's field have been beautifully demonstrated in the laboratory by Brüche.

Minute particles in varying numbers are coming continually from the sun. Once within the earth's magnetic field, these electrified corpuscles are entrapped by the outermost lines of magnetic force. When the particles pass through the atmosphere, they cause the air to glow by their impact, and produce brilliant polar-light displays. From simultaneous photographs of aurora, taken at two stations a known distance apart, it has been found that polar-light beams generally do not come closer to the earth's surface than about 50 miles; some come no closer than 300 miles or more. Since the height of polar lights is in no case less than 50 miles above the ground, the conclusion is drawn that the magnetic variations and disturbances also have their origin in electrical phenomena taking place at least at greater heights in the atmosphere. This has been confirmed in every respect and the study of the magnetic variations is one of our main sources of information about the constitution of, and the phenomena in, these outermost and inaccessible regions of the atmosphere.

Thus, inspection of data indicates an apparent interrelation of the earth's field with the sun. The sun's magnetic field, even though it is 100 times that of the earth, is far too weak to make its magnetic influence felt at the earth, 93,000,000 miles distant. It is much more probable that solar influences on the earth's magnetism are connected with enormous streams or clouds of particles, atoms, ions, and electrons ejected from the active regions of the sun, which travel through space and from time to time reach the earth after 1 or 2 days, and impinge upon its atmosphere, causing magnetic storms, which often disturb electrical communications by cable, telegraph, and radio.

The regular daily magnetic variation apparently is the effect of other radiations from the sun, which travel with the velocity of light and are absorbed in the highest levels of the air, and which make

these layers electrically conducting. These conclusions drawn many years ago from magnetic observations became more important after the invention of wireless telegraphy, because by them we may explain why wireless waves are bent around the earth along these same conducting layers.

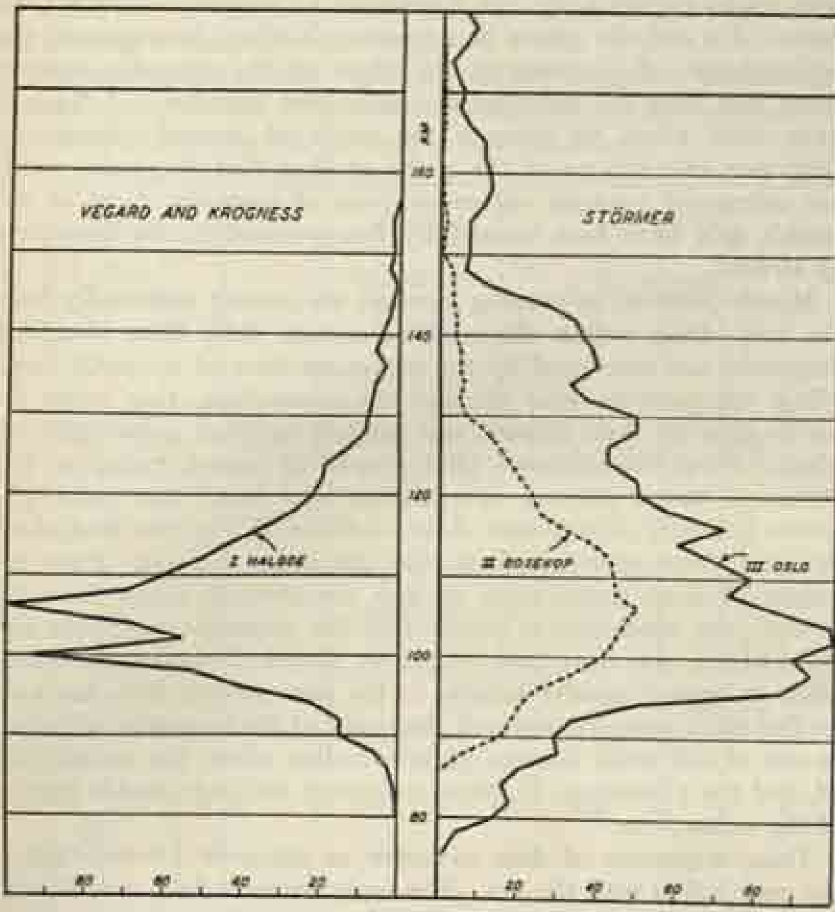


FIGURE 7.—Total distribution of auroral forms and of lower limits for auroral heights.

The range of diurnal variation varies with magnetic character. Statistical studies, which tend to smooth the violent irregular fluctuations, have led to the identification of three main features of a magnetic storm. These are: (1) An everywhere similar but unequally large general source according to universal time; (2) a superposed diurnal movement according to local time, differing characteristically from the ordinary diurnal variation on quiet days; and (3) an aftereffect, which gradually subsides in the recovery during the days after a storm.

Magnetic activity provides one of the means of determining another time change, namely, that of an 11-year cycle apparently agreeing with the well-known cycle in sunspot frequency. Latest investigations have shown, however, that solar activity as indicated in its reflected effect in the magnetic field is not completely or always represented by sunspottedness or other phenomena which astrophysicists observe on the sun's surface; magnetic observations apparently reveal distinct solar influences of another kind and add in this way to our knowledge of solar physics.

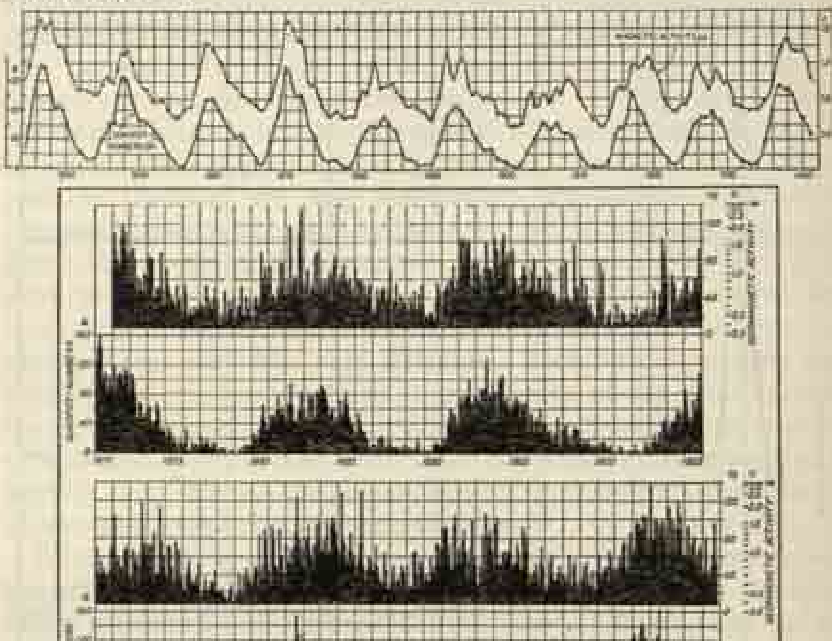


FIGURE 8.—Geomagnetic activity and relative sunspot numbers. Upper, for annual means, 1835–1941; and lower, for monthly means, 1872–1941.

As the earth revolves about the sun during the year there are corresponding fluctuations in magnetic activity, the maximum or crest occurring during the equinoctial months of March and September, and the minimum or trough in the solstitial months of June and December. This is revealed in the annual variation of magnetic activity deduced from examination of many years' observations obtained at several observatories. Graphs of sunspot areas for years with many and years with few sunspots plotted against days before magnetic storms give further evidence of relations between solar activity and magnetic activity.

As has been stated, the recurrence of sunspots with the sun's rotation varies for different solar latitudes from 27 to 28 days. Therefore, if solar activity has an effect on the earth's magnetic field, we may expect some like recurrence in geomagnetic activity.

The simplest method of establishing the existence of a recurrence tendency and of determining any average of its interval is the superposed epoch method due to Chree. This proof depends only on magnetic data without any reference to the sun. The average character figures for epochs of 5 days per month that have the highest character

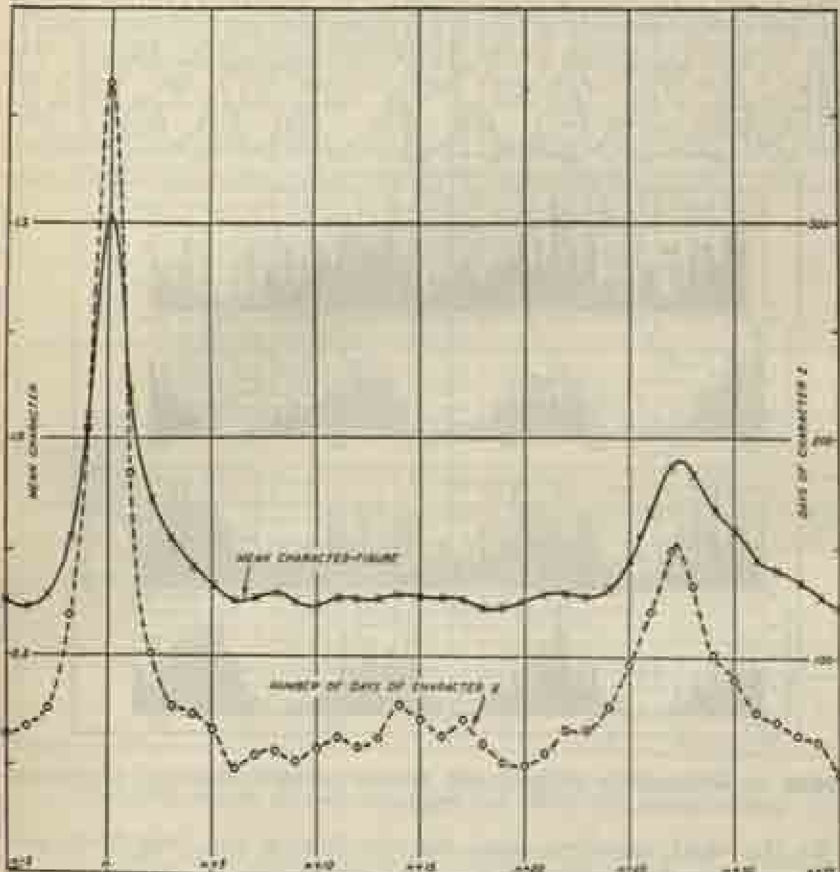


FIGURE 9.—Superposed-epoch method to show solar period in geomagnetism. (After Chree.)

figure of magnetic activity and for each of the 5 preceding and 30 or more days following are compiled. When plotted, these averages show first marked peaks corresponding to the selected epochs followed by repetitions of the peaks after 27 days, thus indicating the tendency for magnetic disturbance to recur in about 27, 54, and 81 days. The same method applied to selected epochs of the 5 quietest days per

month shows the recurrence tendency equally well, with the initial and repeated peaks after 27 days inverted because their character figures are below the average.

A modification of this method consists in charting character figures for all days for a number of years. On such a chart, in order to compare the magnetic character with conditions on the sun, which rotates once in about 27 days, appropriate symbols indicating the magnetic character of each day are placed in rows, the date of the first day in each row being indicated at the left, and each successive row beginning 27 days later. In order to emphasize the continuity of the series, the symbols showing magnetic character for the first 9 days of the next row are repeated. Charts of this kind show vertically elongated clusters covering one or more rotation periods. Similar time patterns for the sunspot cycle indicate this cycle to be more strongly manifested on the sun than in geomagnetic disturbance. In this method, developed by Bartels, one may concentrate graphically information obtained during many years by the world net of magnetic and astronomic observatories. The magnetic clusters are at times found to be more pronounced for periods when the sun is free or almost free from spots. Even for periods when both are disturbed the respective time patterns are often very different. Therefore, it is clear that sunspot numbers are not always a good index of any solar agencies that cause magnetic disturbance on the earth. Thus, further research on this interrelation calls for a more all-inclusive measure of solar activity than that of the sunspottedness, a matter for the solution of which we must look to the astrophysicist.

Whatever theory of magnetic disturbances may finally be evolved, it is clear that geomagnetism provides us with information regarding fairly persistent solar phenomena, restricted to varying but always well-defined regions on the sun's surface. These are not only of interest for study of the sun, because direct astrophysical observations do not reveal them as yet, but are of even greater interest from the terrestrial standpoint because magnetism records these solar influences only in so far as they actually affect our globe.

IONOSPHERIC AND SOLAR RELATIONS

The conclusion drawn from magnetic variations and disturbances and from polar lights that they have their origin in electrical phenomena at great heights in the atmosphere makes it of interest to study the electrical conditions there. Since we are unable to visit these great altitudes, we have to study the electrification of the upper atmosphere, or ionosphere, from our position on the earth.

More than 60 years ago Balfour Stewart inferred from geomagnetic data the existence of regions in the outer atmosphere of great

electrical conductivity as a source of magnetic and auroral effects observed on the earth. Even over 100 years ago Gauss, the outstanding pioneer in advancing scientific consideration of the earth's magnetic field, referred to this possibility in his earlier writings. Subsequently, such scholars as Schuster, Kennelly, Heaviside, Lorentz, Eccles, and Lamor took part in the development of the concept.

The highly electrified regions outside the earth were again suggested in 1901 in order to explain Marconi's success in sending radio signals across the Atlantic Ocean from England to Newfoundland. Prior to Marconi's proof of the usefulness of radio signals for long-distance communication, the public, including the scientists, were inclined to ridicule his invention as a new gadget that would be limited to communication without wires over line-of-sight distances only. Was it not true that these Hertzian waves traveled in straight lines like light? They would go over the horizon and be lost in space. Hence, it would not be possible to communicate from one point to another over the curved surface of the earth. Both Kennelly and Heaviside independently suggested that a conducting region in the outer atmosphere would be capable of bending radio waves around and returning them back to earth. Radio waves travel with the speed of light, 300,000 kilometers per second. If the frequency or number per second is low, the distance between crests, or the wave length, is long; for example, the wave length for 1,000 kilocycles or one megacycle per second is 300 meters. If the frequency is high, the wave length is short; for example, the wave length for 15,000 kilocycles or 15 megacycles per second is 20 meters. The short waves vibrate more rapidly and have greater penetrating power.

It was not until 1925 that Appleton in England and Breit and Tuve in America, using radio waves by somewhat different methods, succeeded in directly "seeing" the radio-reflecting region of the outer atmosphere. The echo-method technique developed by Breit and Tuve for this purpose has now been adopted almost universally. By this method a short pulse of radio waves is sent upward and the time measured for the echo to return. An equivalent height to which the wave would travel can be computed, assuming it to have traveled at the velocity of light. The density of ionization which reflects the wave at this level is measured by the wave frequency transmitted. Corresponding to each wave frequency is a particular density of ions which will reflect the wave.

There has been developed by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington and the National Bureau of Standards from the earlier experimental equipment a so-called ionospheric apparatus which produces records automatically by photographing echoes of vertically directed variable-frequency radio

waves. Study of these records soon confirmed the fact that, instead of only one "Kennelly-Heaviside" layer, there are several layers or stratifications of ionization.

Present convention has adopted the term "ionosphere" to include all these regions. Low-frequency radio waves penetrate to relatively low heights (possibly 60 miles above the earth). These low frequencies—or the long waves—include the radio spectrum used by our local broadcasting stations. The high frequencies—or the short waves—are used for international broadcasting over great distances. Higher frequency radio waves are more penetrating and seek greater densities of electrical charges before being reflected. These may penetrate to 200 or 300 miles above the earth. Radio waves of still higher frequencies do not encounter enough concentration of electrical charges in the ionosphere and they may penetrate completely through and be lost in space.

These penetration frequencies measure the apparent height from which echoes are received. There are three important ionized layers in the outer atmosphere under direct influence of the sun. One is at a level of about 100 kilometers, another at about 225 kilometers, and the third at some 350 kilometers. The two upper layers do not exist separately everywhere, but merge when the sun is low and form a single layer in the night. At noon the highest layer reaches maximum height directly under the sun. The heights of the layers are not constant but change with time of day and season, with latitude, and even with time along the sunspot cycle.

Radio exploration of the ionosphere is accomplished by automatically shifting the wave frequency over a range about 500 to 16,000 kilocycles per second. An automatically recorded reference line for the surface of the earth provides the base from which to measure heights of radio echoes. At wave frequencies up to 4,000 kilocycles per second, radio echoes are returned from heights at about 100 kilometers. Frequencies above 4,000 kilocycles show a sudden jump to a higher reflecting region. At greater frequencies the waves penetrate, in general, farther into the rarefied atmosphere until at 12,000 kilocycles per second there are no reflections from the ionosphere and the waves pass out into space.

Continuous operation of ionospheric apparatus reveals that there are striking differences between normal day and night conditions. In general, the number of electrical charges in the ionosphere builds up during the day under the influence of the sun's rays. During the night, when the sun's rays are cut off, the ionization decreases. There are also extensive changes in the ionosphere, from one season to another. Complete knowledge of the variations and characteristics of

the ionosphere permits interpretations of variations in the earth's magnetism and of radio communications.

The programs of ionospheric research, which are incorporated with the other scientific investigations at the observatories of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington near Huancayo (Peru), Watheroo (Western Australia), and College (Alaska), and of the National Bureau of Standards near Washington, supplement our understanding of normal as well as abnormal relationships between the sun and the earth. Among the more normal relationships is the effect of sunspots upon the ionosphere. This is illustrated by the average relationship that large

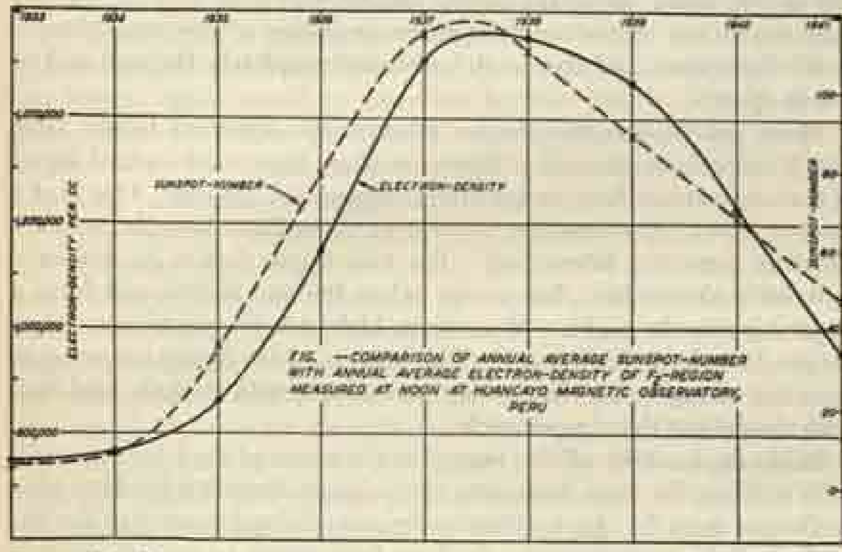


FIGURE 10.—Comparison of annual average sunspot numbers with annual average electron density of F_2-region as measured at local noon, Huancayo Magnetic Observatory, Peru.

numbers of sunspots are in general associated with large numbers of electrical charges in the earth's outer atmosphere. The average annual maximum density of electrons at noon as measured in the region of the highest layer at the equatorial station of Huancayo follows the annual averages of sunspot numbers—from minimum to maximum of sunspots the change of average annual ion density is about one to three. The two lower regions show changes, similar in form, but of smaller magnitude, with an increase in density only by some 50 percent. The geomagnetic diurnal variation changes in value by some 50 percent from minimum to maximum of sunspot activity. This corresponds under like conditions to observed changes in ion density of the two lower regions, but is greatly different from the change of some 300 percent in ion density of the third region. Evi-

dently the last is an important factor in the geomagnetic diurnal variation.

Of the abnormal ties between sun and earth, the radio fade-out is the one outstanding example of a direct relationship, namely, the observed association of the bright chromospheric eruption on the sun's surface, the simultaneous disappearance of radio echoes, and characteristic pulse in the earth's magnetism. McNish has shown that the unique geomagnetic change associated with the fade-out is an augmentation of the normal diurnal variation at all places where it is observed. Because the atmospheric region below 100 kilometers appears almost solely affected during the fade-out, it seems probable that not only the unique geomagnetic pulse but also the whole diurnal variation, of which the pulse is but an augmentation, arises from electric current flow at about these levels.

Thanks to the extensive network of stations distributed over the earth keeping constant watch for these chromospheric eruptions, a similar and older network of magnetic observatories, and the channels of radio communication, data on these associated phenomena accumulate rapidly. Dellinger's compilation of such data soon showed that chromospheric eruptions always accompany fade-outs and the concomitant magnetic changes. The first actual simultaneous observations of a fade-out, a bright eruption in the solar chromosphere, and a unique baylike kind of geomagnetic pulse were obtained on August 28, 1937, at the Huancayo Magnetic Observatory in Peru. Characteristically the echoes disappeared rather suddenly at a level between 70 and 90 kilometers. This is probably because of absorption produced by the intense ionization of this region by the ultraviolet light emanating from the solar eruption.

Another powerful influence upon terrestrial conditions is the result of bombardment of the earth by minute particles which are shot out in streams from the sun. This is as though streams of small particles were sprayed toward the earth as from a moving nozzle. The development of such streams is generally associated with large or active sunspot groups. These streams travel relatively slowly and normally require about 1 to 4 days to cover the distance between sun and earth. When they reach the earth's upper atmosphere, their effect is felt and observed as magnetic and ionospheric storms as well as auroral displays.

The magnetic storm of March 1, 1941, associated with the passage of a large active sunspot group across the sun's central meridian about 2 days before, gave a typical example of the behavior of the ionosphere caused by corpuscular radiation during a magnetic disturbance. The ionospheric effect was produced in this case as a result of the earth's bombardment by these solar particles. We may compare the normal records on the undisturbed day, February 28, 1941,

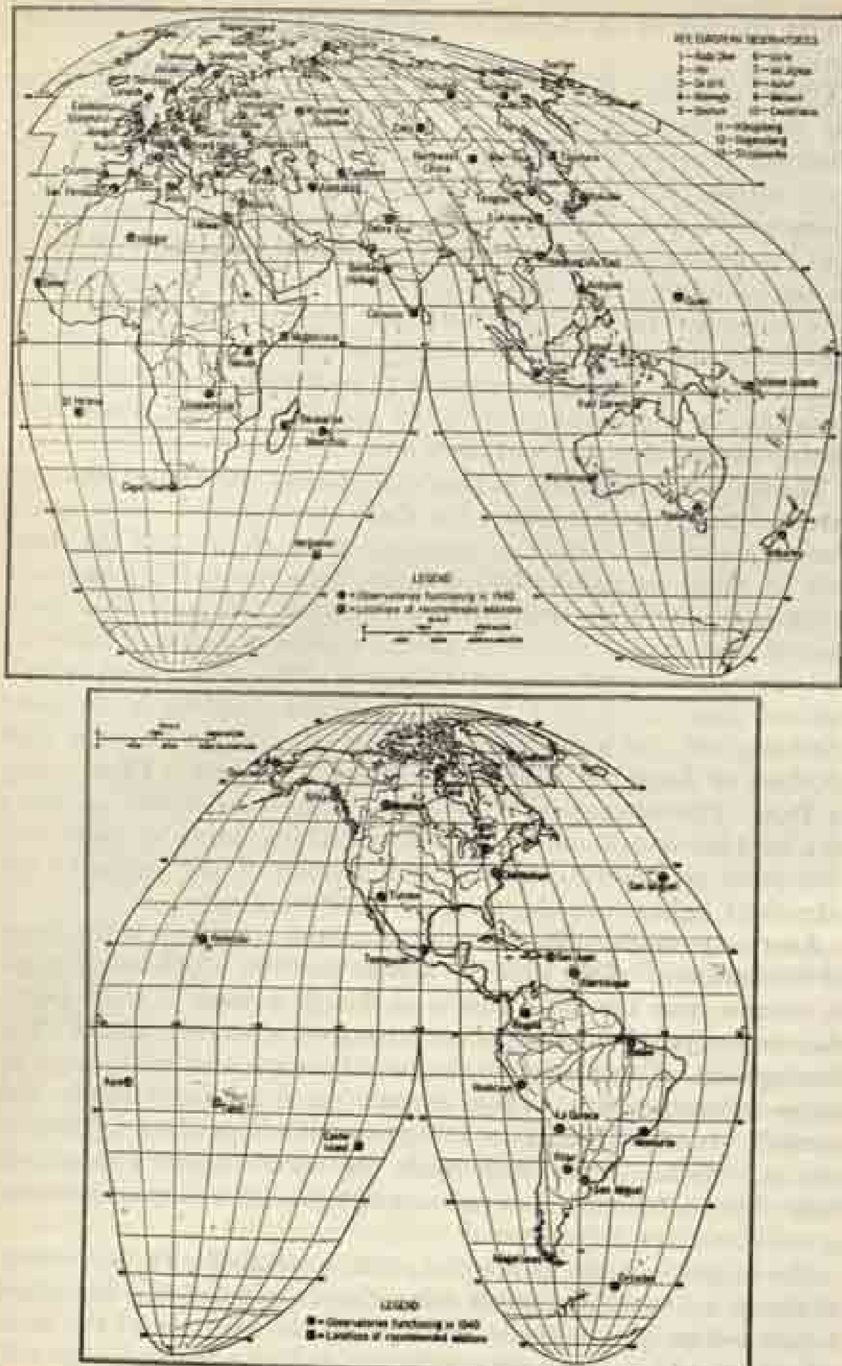


FIGURE 11.—Established magnetic and electric observatories in Eastern and Western Hemispheres, 1940, and additions recommended by International Union of Geodesy and Geophysics.

with the abnormal records during the same time on the next day, March 1. It immediately appears that the disturbances blew the ionosphere out into space—an effect especially pronounced during the beginning of such disturbance. For this case the average density of electrical charges during the magnetic storm was reduced to approximately one-third of the normal value observed on the previous day.

The nature of the relation between ionospheric and magnetic disturbances is not yet fully evident. Ionospheric changes apparently arise in part because of wave radiation and in part because of partial (corpuscular) radiation from the sun. This part of the investigation of geomagnetism has only begun.

EARTH CURRENTS

Electric currents produced by some natural agency circulate in the earth at all times as was discovered after the introduction of the telegraph 100 years ago. These earth currents are closely related to changes in the earth's magnetism and bear some relationship to polar lights and to certain conditions which affect radio transmission. When polar lights appear, earth currents surge to and fro in an unusual manner. These surgings often occur even when polar lights are not sufficiently intense or extensive to be seen. They occur also in equatorial regions where polar lights are never seen.

They produce effects, resembling static in radio, which interfere with the sending of messages. A study of these interferences as first observed by Barlow on telegraph lines in England in 1847 shows that they are due to electric currents which come from the earth and which to some extent are present at all times.

Most earth-current storms which are observed in the middle latitudes occur simultaneously everywhere on the earth, and hence these must be due to an influence which acts directly upon a large part of the earth. From a statistical study, a definite tendency is found for an earth-current storm to recur every 27 days—once more giving evidence of solar and terrestrial interrelationships.

RECENT GEOMAGNETIC AND AURORAL DISTURBANCES

The present cycle of solar and geomagnetic activity has been noteworthy because of two of the greatest magnetic storms ever recorded since the introduction of photographic recording in 1859. These, as will be seen from table 1 of great magnetic storms during 1859 to 1941, indicate the current cycle as the most active in the recorded annals of geomagnetism.

TABLE 1.—*Great magnetic storms* [1]

Date	Ranges [2]			Station	Remarks
	Declination	Horizontal intensity	Vertical intensity		
	′	γ	γ		
1859, Aug. 28–Sept. 7	140	700 (?)	400 (?)	Greenwich, England	
1872, Feb. 4		>900		Bombay, India	Aurora seen at Bombay.
1882, Nov. 17–21	115	>1,090	>1,000	Greenwich, England	Largest sunspot group of that cycle on sun.
1903, Oct. 31–Nov. 1	186	>950	>950	Potsdam, Germany	
1909, Sept. 25	210	>1,300	>1,100	Potsdam, Germany	Lasted only about 10 hours.
	68	900	235	San Juan, Puerto Rico	
1921, May 13–16	192	1,060	1,100	Potsdam, Germany	Aurora seen at Samoa.
	>120	>800	>1,000	Cheltenham, Maryland	
	98	>1,100	453	Watheroo, Western Australia.	
1938, Apr. 16	328	1,900	600	Potsdam, Germany	Lasted only about 10 hours.
	25	1,320	118	Huancayo, Peru	
	201	1,120	1,020	Cheltenham, Maryland	
1940, Mar. 24–25	133	2,300	900	Potsdam, Germany	Severe disturbance of power circuits in North America.
	137	850	1,100	Cheltenham, Maryland	
	21	1,390	122	Huancayo, Peru	
1941, Sept. 18–19	364	2,544	1,390	Cheltenham, Maryland	Remarkable auroral display in eastern and midcentral parts of United States.
	71	688		Watheroo, Western Australia.	

[1] Table 1 is an extension of one appearing in Geomagnetism, by S. Chapman and J. Bartels.
[2] Expressed in minutes of arc for declination and in γ (1γ=0.00001 gauss) for horizontal and vertical components.

The first of the nine great storms listed is the classic storm of August 28 to September 7, 1859. Carrington and Young over 80 years ago interpreted certain features of that storm as indicating the simultaneity of solar eruptions and magnetic disturbances, but this opinion was abandoned by other investigators because they looked for it in vain in later great magnetic storms. If the radio fade-outs had not given such strong evidence of ionospheric disturbances simultaneous with solar eruptions, it is not impossible that the comparatively small, though distinct, terrestrial magnetic effects would still have escaped detection. Because of the rarity mentioned, and not only for historical reasons, it may be of interest to recall here the original records of the classical case which started the controversy.

The records for 3 days show comparatively quiet conditions on August 30 and 31, 1859, the brief baylike disturbance beginning at $11^h\ 18^m$, September 1, and the outbreak of the second great storm at $4^h\ 50^m$, September 2. General Sabine stated that "this great magnetic storm, for excessive violence of character and length of duration, had never been surpassed by any similar phenomenon which has occurred in my long and varied experience."

R. C. Carrington's report included a drawing showing the large spot in heliographic latitude 20° north and near the central meridian on September 1, 1859. He noted in particular two patches of intensely bright and white light of brilliancy fully equal to that of direct sunlight. The instant of the first outburst was within 15

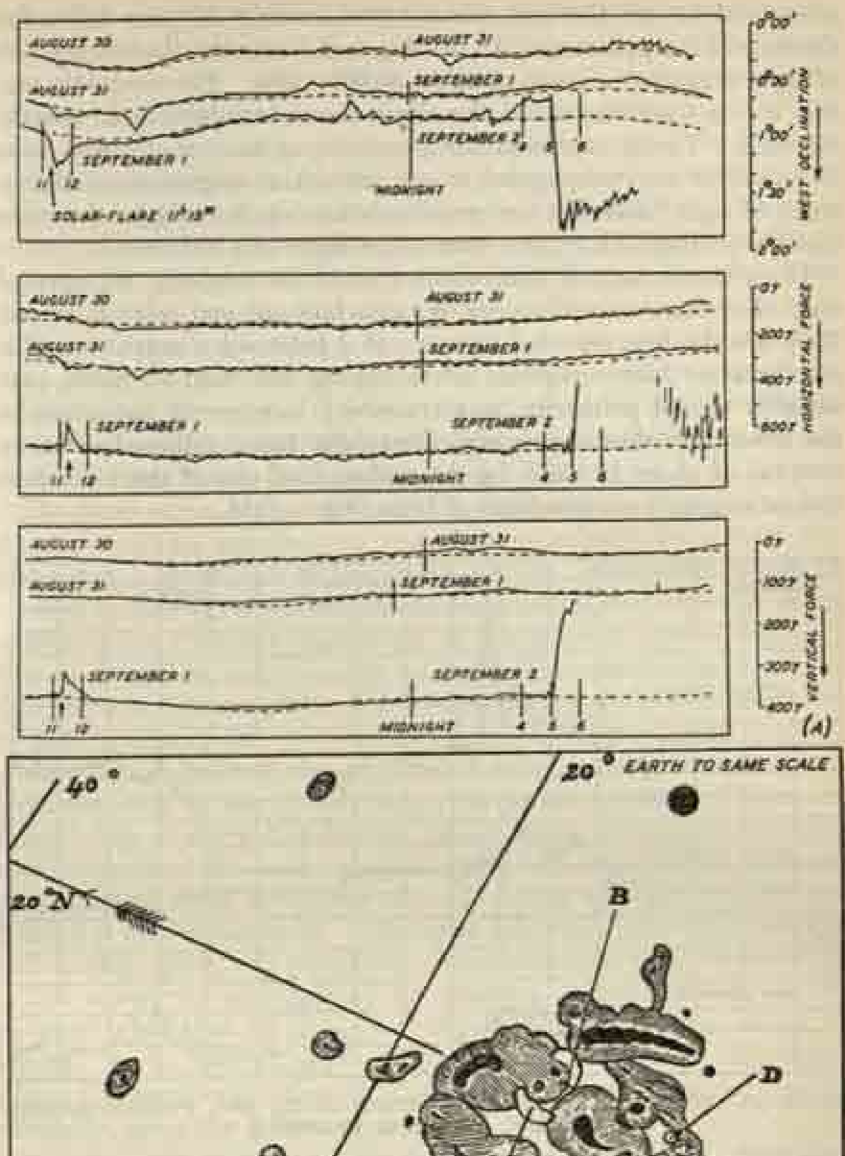


FIGURE 12.—(A) magnetograms, 10^h13^m, August 30, to 10^h09^m, September 2, 1859 Kew Magnetic Observatory, England, showing short bay disturbance caused by ultraviolet light and beginning simultaneously with solar flare at 11^h15^m, September 1, and beginning, 18 hours later, of great magnetic storm caused by solar corpuscles. (B) solar sketch, September 1, 1859, by R. C. Carrington. (After Balfour Stewart.)

seconds of 11h 18m Greenwich mean time, and 11h 23m was taken for the time of disappearance. In this lapse of 5 minutes, the two patches of light traversed a space of about 35,000 miles. The magnetic motion was in itself slight and of a character and magnitude frequently recorded. Young expressed the prophetic opinion that these solar disturbances are "propagated to our terrestrial magnetism with the speed of light" and that the casual relationship is "only in the sense that the pulling of a trigger 'causes' the flight of a rifle-ball."

Thus, these classical observations could be properly interpreted only after the recent discovery of radio fade-out and solar relations. They are the first recorded instance of a large solar eruption and a simultaneous large magnetic effect lasting less than an hour, presumably caused primarily by a transitory increase of ionization in the ionosphere due to excessive ultraviolet light, followed after an interval of about 18 hours by the outbreak of one of the nine most violent magnetic storms observed from 1859 to 1941.

FIGURE 13.—Wide-range magnetogram, March 24-25, 1940, Potsdam-Niemegk, Germany. (After G. Fanselau.)

The magnetic storm of March 24, 1940, one of the greatest ever recorded, was an event of unusual geophysical interest. This storm was accompanied by auroral displays which, however, were not unprecedented. The accompanying disruption of wire communication by electric currents induced in the earth produced senseless jumbles of letters in teletype equipment. These earth currents were of such magnitude that electric power systems were severely affected—the first time such effects have ever been reported. The reports of interference with power transmission, especially at stations in the eastern United States and Canada, were at first doubted by electrical engi-

neers and magneticians. However, the accumulated reports indicating connection between the storm and the power-line disturbances proved convincing. The evidence shows that the storm produced earth-current gradients amounting to about 10 volts per mile. Thus an increased practical importance of cosmical research in geomagnetism has been shown, for the lengthy observations extending over a century supply definite information on the probability of occurrence of such storms and therefore on the extent to which it is advisable to improve electrical installations to avert their effects. Because of the theoretical and practical importance of obtaining complete records of the infrequent great magnetic storms, a number of observatories have added less sensitive equipment to the more sensitive types heretofore exclusively used. Thanks to these insensitive magnetographs, we have complete photographic records of the very great disturbances of April 1938, March 1940, and September 1941.

The great storm of September 18–19, 1941, while not producing any great power-line interference, was most remarkable in auroral displays over a great part of the United States. This storm is also of interest in that H. W. Wells, of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, several days before its inception, had formally warned radio-transmission engineers that disturbed geomagnetic and ionospheric conditions might be expected September 18. He was able to make this prediction through close study of daily reports of areas, numbers, and locations of sunspots supplied by the United States Naval Observatory. Following several days of slight disturbance, violent fluctuations in the direction and intensity of the earth's magnetic field began about 11 p. m., eastern standard time, September 17. Maximum activity was between 1 and 3 p. m. September 18. The usual difficulties with long-distance, radio, telegraphic, and telephonic communications were experienced.

The storm was accompanied by extensive auroral display—an occurrence which one living in our latitude has seldom the privilege of seeing. A. G. McNish, of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, who observed the display carefully, gives the following account:

> But nature had scheduled her choice act for the evening hours. Those who watched the evening Sun go down were aware of a strangely persistent glow in the northwestern sky. As the sky darkened, distinct rays were visible in the northern sky, brightening, fading, and continually changing. By 8 p. m. the entire sky was filled with rays apparently converging to a point near the zenith to produce a vivid coronal formation. Various forms of auroral activity, rays, curtains, extensive arcs, and flickering rays resembling searchlight or airbeacon beams continued until almost dawn September 19. Some auroral activity was noted during the preceding and following nights, neither being comparable with the display of September 18–19.

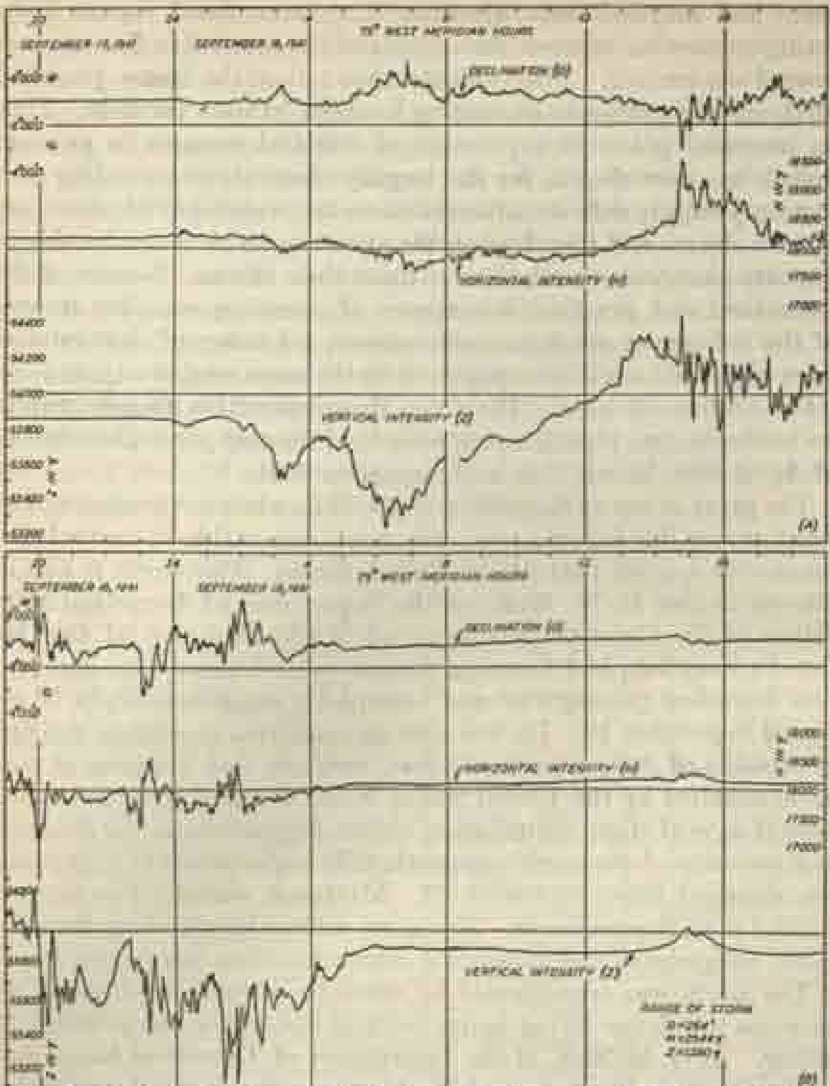


FIGURE 14.—Records of magnetic storm (*A*) September 17–18, 1941, and (*B*) September 18–19, 1941, Cheltenham Magnetic Observatory, Maryland. (Courtesy of U. S. Coast and Geodetic Survey.)

The coronal display was visible simultaneously in widely separated parts of the country. To all observers everywhere the rays seemed to converge toward a point slightly south of the zenith. Actually, of course, there was no convergence. The particles shot off from the Sun, being electrically charged, can not freely cross the Earth's magnetic field and must travel in the direction of the magnetic lines of force. At Washington, the lines of force are tilted about 20° southward from the vertical while farther north the tilt is less. Thus all observers were viewing a bundle of closely parallel rays, extending tens or hundreds of miles upward in the rarefied atmosphere, and appearing to con-

verge toward what is called the magnetic zenith just as railroad tracks appear to converge toward a point on the horizon.

Photographers in Long Island and New York State obtained negatives, and through their courtesy I am happy to exhibit copies which fully justify Mr. McNish's account as regards brilliancy and variety of the auroral activity.

The bright chromospheric eruptions in sunspots photographed in the light of luminous hydrogen vapor show the bright eruption starting on September 17 at 6:26 a. m. Pacific standard time, and the greatly increased brightness of the eruption 10 minutes later.

COSMIC-RAY RELATIONS

A connection between geomagnetic and cosmic phenomena has recently been discovered—the world-wide decrease in the intensity of cosmic radiation during great magnetic storms. Although such an effect was predicted over 6 years ago, observational verification was not achieved until the occurrence of the great magnetic storms of our present sunspot cycle. The effect was noted by Forbush during the great storms of April 1937, March 1940, and September 1941. Since the magnetic moment of the earth increases during the main phase of a magnetic storm, a decrease of cosmic radiation during that time is to be expected on the basis of the well-established variation of cosmic-ray intensity with geomagnetic latitude.

The superposed-epoch method is useful also to show correlation between cosmic radiation and the geomagnetic field. Time variations of cosmic-ray intensities, whose origin probably is deep in space, are now measured to within a fraction of 1 percent. This made possible a real comparison with geomagnetic changes by Broxon in 1941. He showed the simultaneous average variations of cosmic-ray intensities and of international daily magnetic character figures by superposed epochs of supernormal and subnormal cosmic-ray intensities. The cosmic-ray intensity is practically always lower for the five international magnetically disturbed days than for the five international magnetically quiet days of each month. These results confirm the inverse correlation between cosmic rays and magnetic disturbances as previously shown by Forbush.

The 13½-day and 27-day waves in cosmic-ray intensity are closely associated with those for character figure and magnetic horizontal intensity. This directs attention to a possible means by which cosmic-ray data might serve to establish the existence of a general solar magnetic field.

LABORATORY APPROACH

Most recent of promising attacks on the many problems indicated above is in the laboratory through investigation of the laws governing the interaction of the magnetic particles composing all matter.

All the actions and reactions in the world of physical things may be expressions of three fundamental forces—gravitational, electromagnetic, and nuclear. All three may ultimately be reduced to different aspects of the same all-pervading, all-inclusive type. Perhaps some

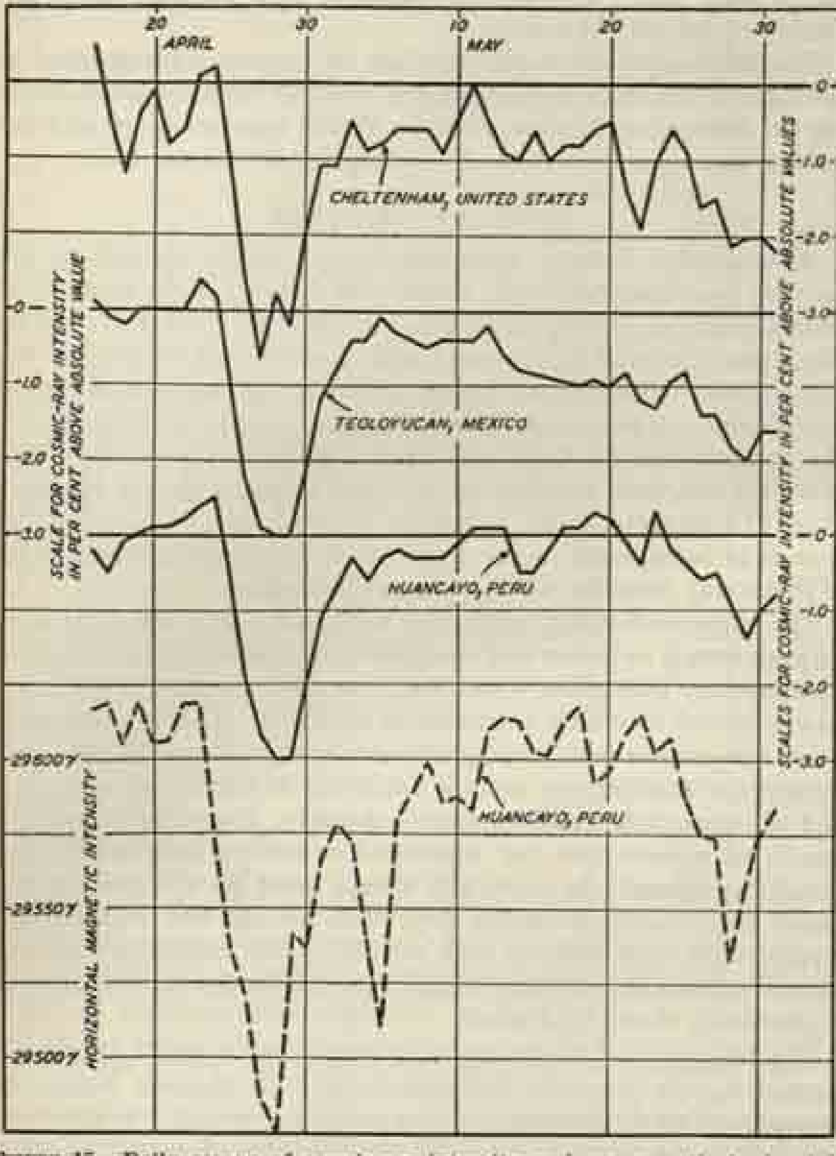


FIGURE 15.—Daily means of cosmic-ray intensity and geomagnetic horizontal-force component, showing effect of geomagnetic storm of April 25–30, 1937, on cosmic-ray intensity.

obscure atomic effect of the extremely high pressures of the centers of such bodies as the earth and the sun may be the cause of their magnetization. Therefore, experimental studies of nuclear physics

through the use of high voltages with the electrostatic generator and the cyclotron and at high pressures may give better understanding of relations between the constant generation of subatomic forces in the sun and their terrestrial effects.

CONCLUSION

In conclusion, may I hope to have left with you some impression of the interrelationships between the ever changing but quiet variations of the earth's magnetic field and the swirling, tumultuous events on the sun. These interrelationships have made possible the electrical exploration of the high atmosphere far above the limits accessible to aircraft. Less than a decade ago this was thought to be beyond human attainment, and hopes of such exploration forecast by Balfour Stewart, Kennelly, and Heaviside existed only in the speculations of intrepid, persistent scientific investigators. Another great step has thus been taken toward definite knowledge of the intimate relations between the earth and the sun which play so material a part in our lives. Upon that step even now plans are rapidly developing for accurate magnetic exploration at equally great heights to supply the third dimension of the geomagnetic field so long sought to aid in the explanation of the origin of that field.

Today geomagnetism maintains its key position as a thriving branch of geophysics, not only because of its own intrinsic interest, but mainly because geomagnetic conditions give a complete, a faithful, and an intelligible record of those mighty solar and cosmical influences to which the earth and its inhabitants are subjected. We may well agree with the recent statement of an eminent scholar of earth physics that "as in all branches of science where growth is active, we are only partly satisfied with the new knowledge gained; long vistas of unexplored territory invite us onward to 'fresh fields and pastures new.'"

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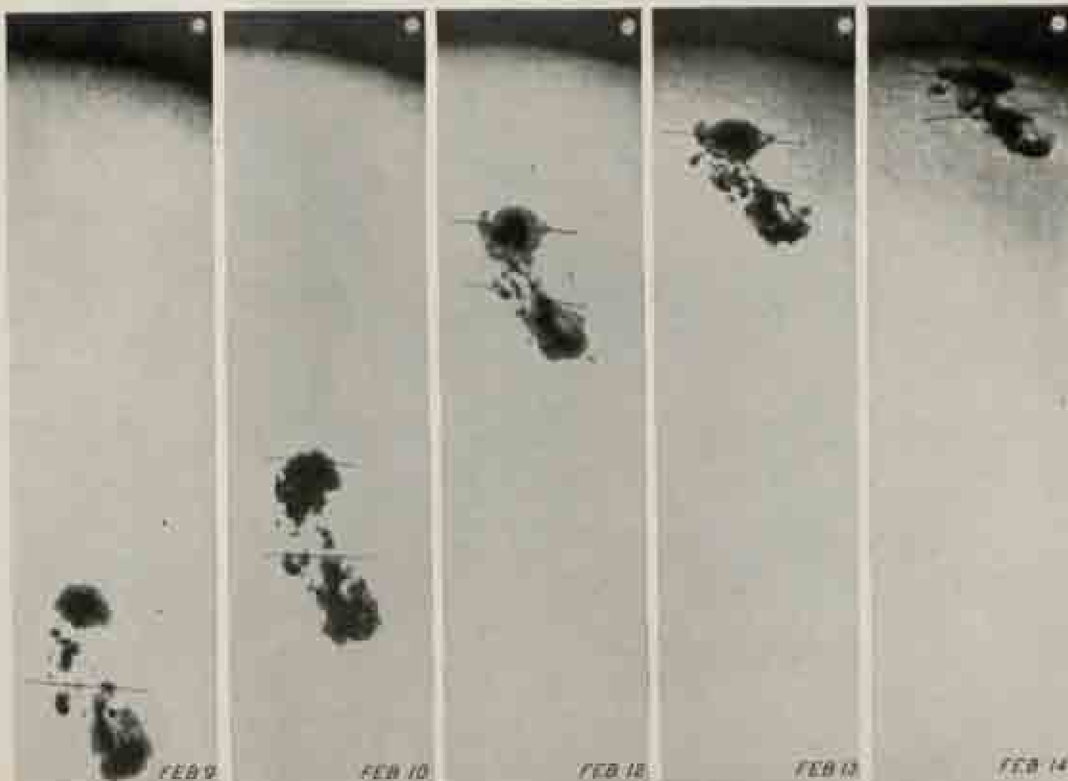
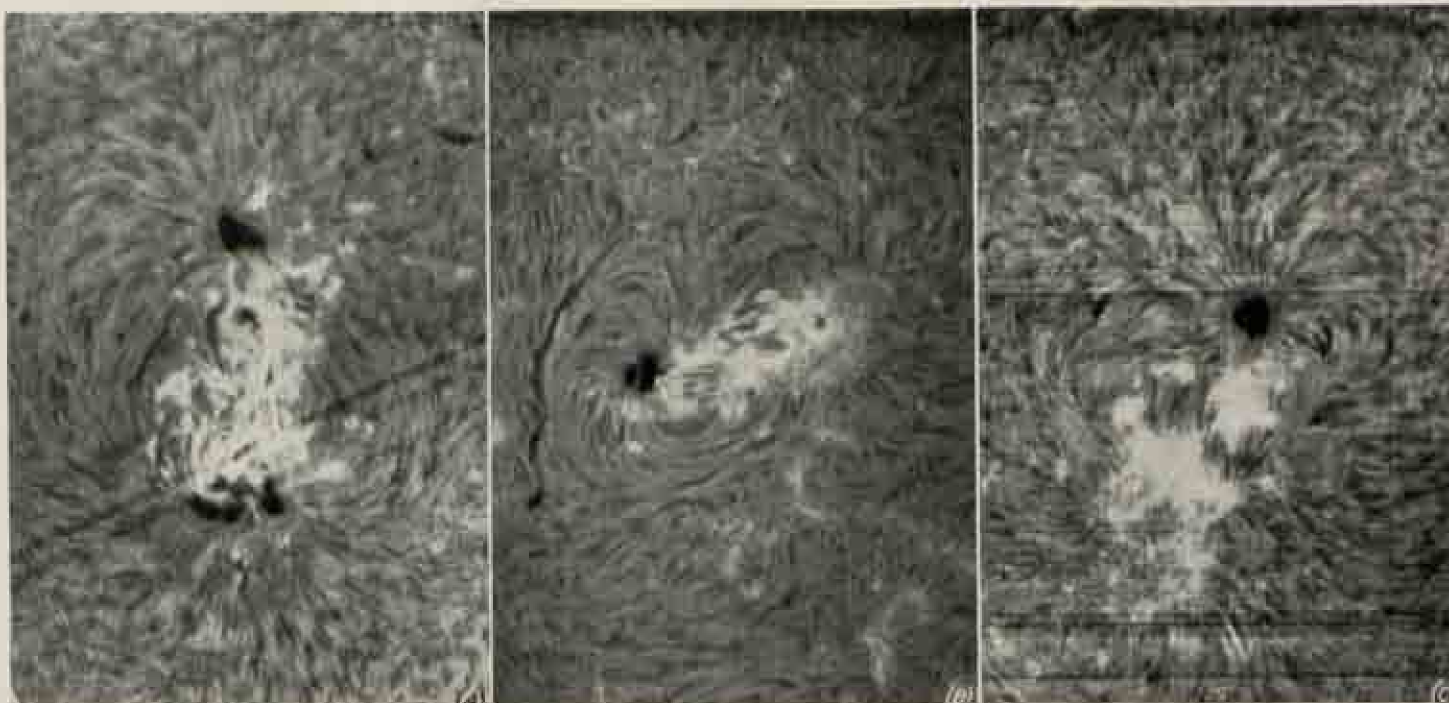


A SUNSPOT GROUP PHOTOGRAPHED ON FEBRUARY 9, 10, 12, 13, 14, 1917.

Sunspots usually occur in groups; single spots vary in size from the smallest that can be seen, a few hundred miles in diameter, to 50,000 miles across. The white disk in upper corner is the comparative size of the earth. During its lifetime the group is carried slowly across the sun's disk by the rotation of the sun. (Photographs by Mount Wilson Observatory, Carnegie Institution of Washington.)

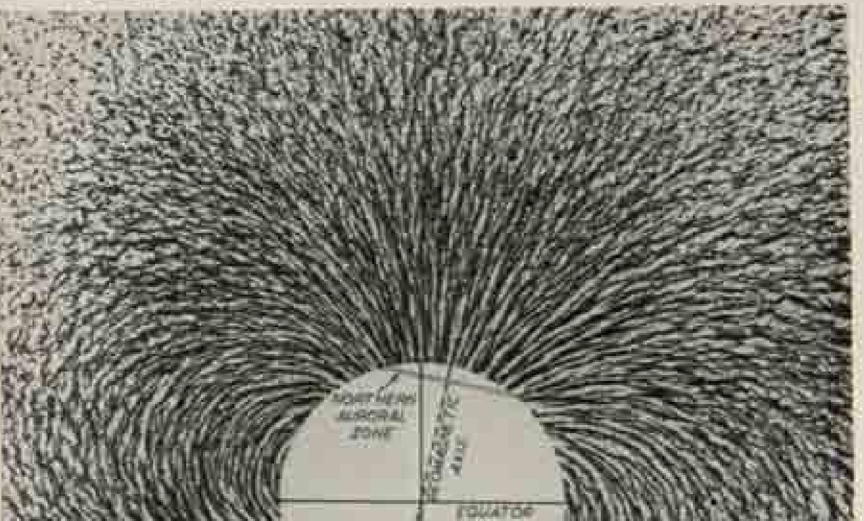
SOLAR CORONA AND PROMINENCES.

(A) Total solar eclipse of May 28, 1900. (Photograph by H. C. Wilson at Southern Pines, N. C.; exposure 30 seconds.) (B) Prominences over an active sunspot group. (Photograph by Mount Wilson Observatory, Carnegie Institution of Washington.)



VARIOUS TYPES OF HYDROGEN FLOCCULI.

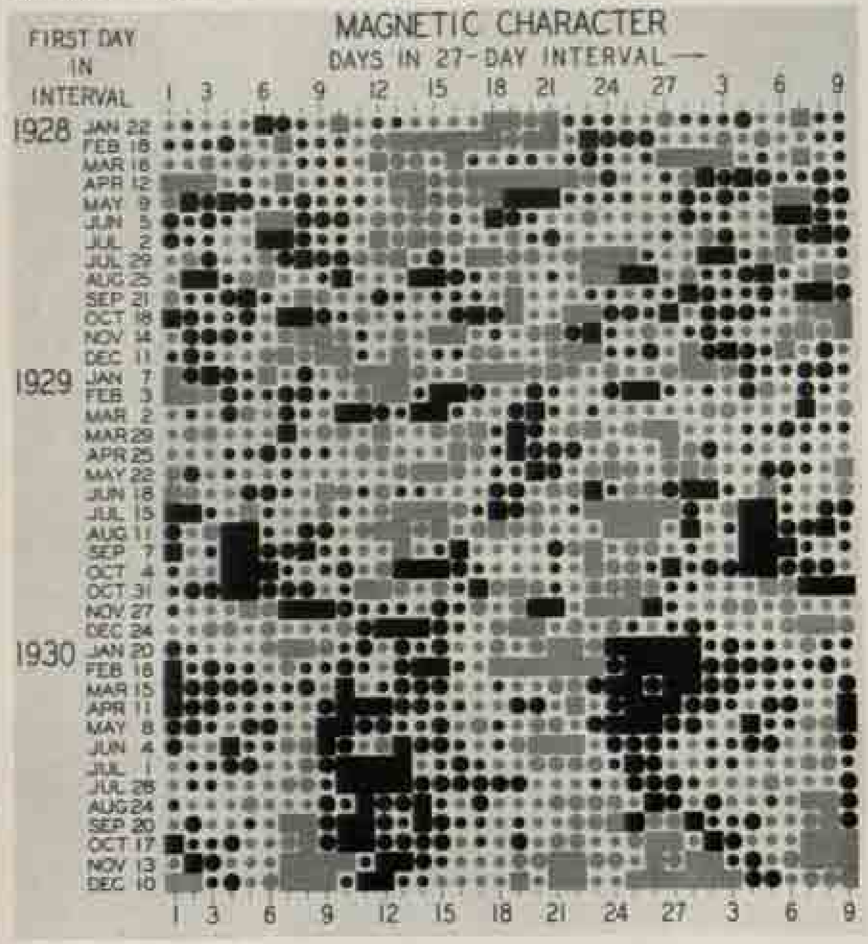
(A) Flocculi over bipolar groups often resemble iron filings over a bar magnet. (B) Flocculi over single spots sometimes have a spiral form. (C) Flocculi over single spots are generally complex, their filaments being radial or curved in either direction. (Photograph by Mount Wilson Observatory, Carnegie Institution of Washington.)



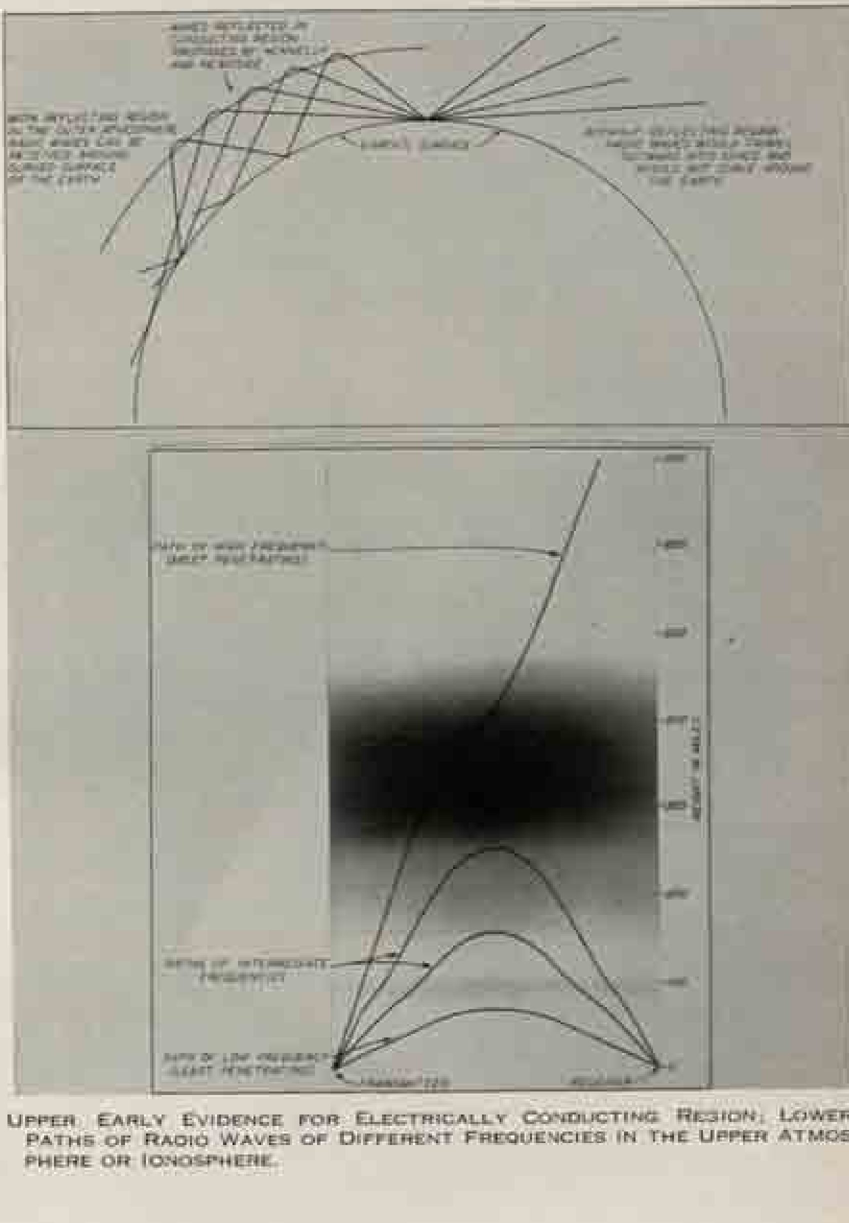
THE MAGNETIC FIELD ABOUT THE EARTH.

HALLEY'S EARLIEST CHART OF MAGNETIC DECLINATION FOR THE ATLANTIC OCEAN, SHOWING ALSO COURSE OF HIS PINK PARAMOUR, 1697-1701

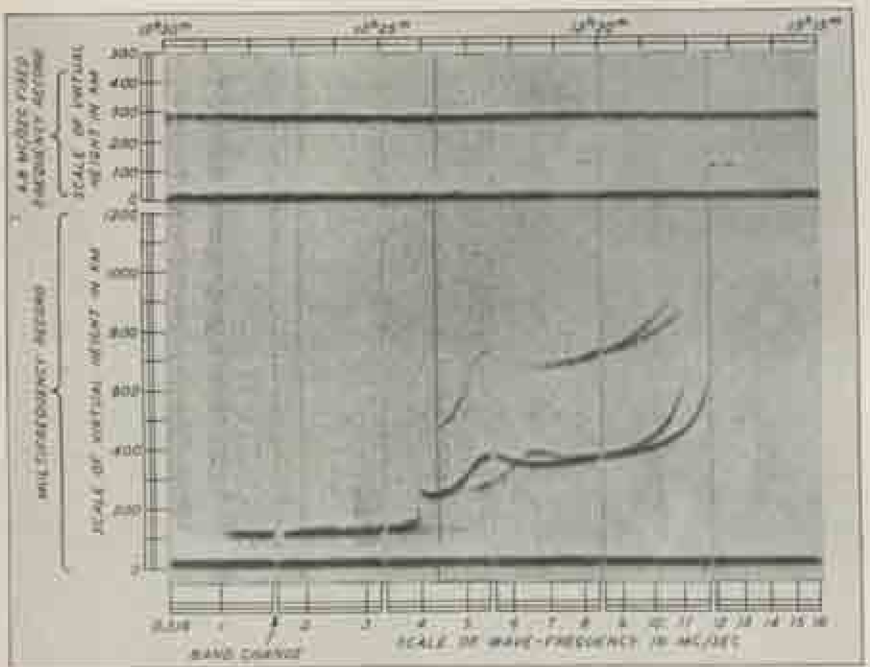
This was the first isomagnetic chart ever published and appeared probably in 1701.



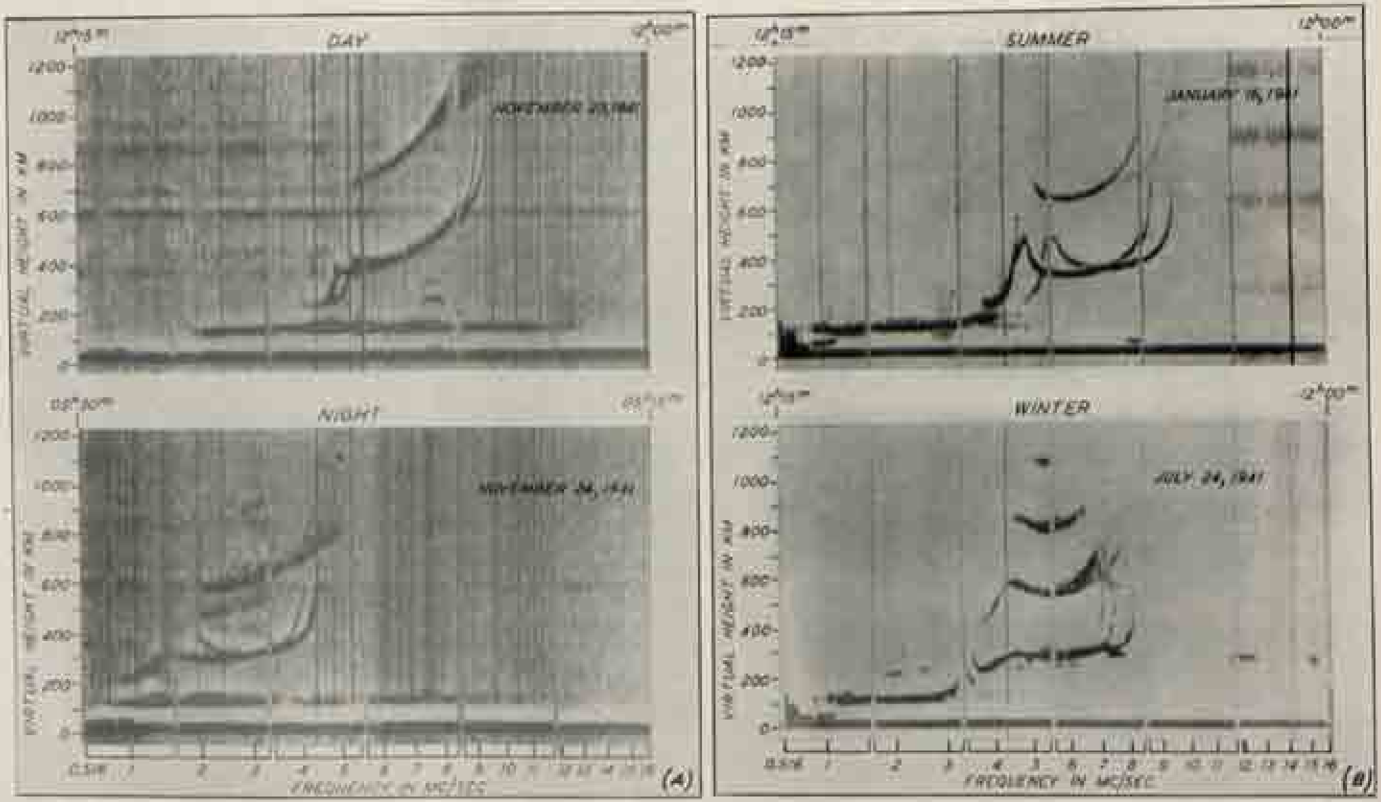
DEMONSTRATION OF 27-DAY RECURRENCE TENDENCY IN GEOMAGNETIC CHARACTER.



UPPER: EARLY EVIDENCE FOR ELECTRICALLY CONDUCTING REGION; LOWER, PATHS OF RADIO WAVES OF DIFFERENT FREQUENCIES IN THE UPPER ATMOSPHERE OR IONOSPHERE.

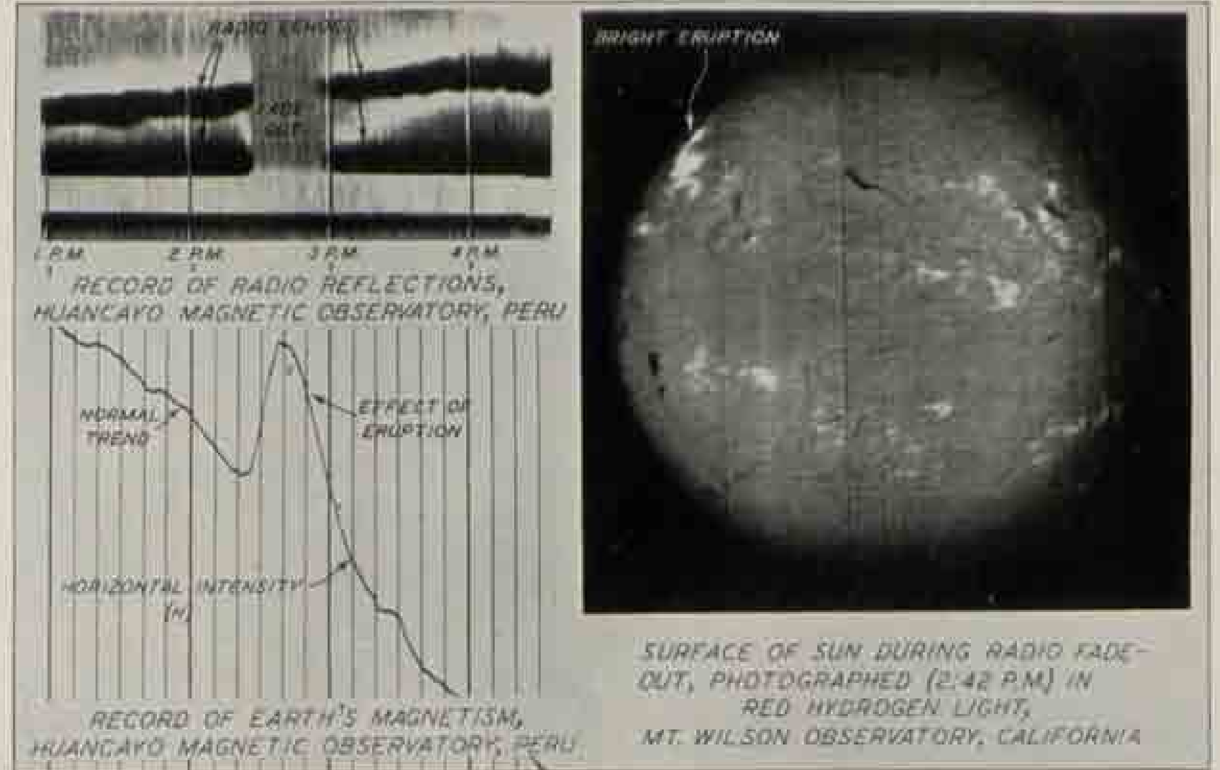


TYPICAL EXAMPLE OF MULTIFREQUENCY SUMMER-TIME RECORD OF REFLECTIONS FROM IONOSPHERIC REGIONS, 13h15m—13h30m, 120° EAST MERIDIAN MEAN TIME, NOVEMBER 20, 1939, WATHEROO MAGNETIC OBSERVATORY, WESTERN AUSTRALIA.

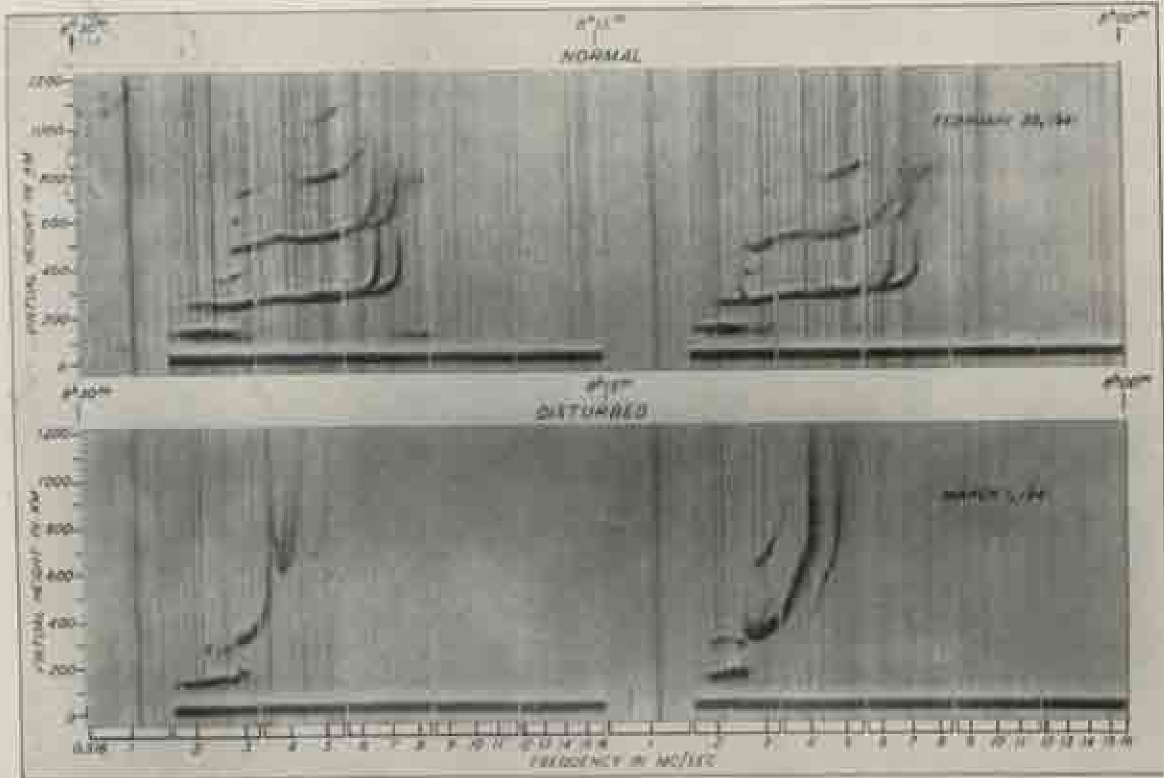


NORMAL MULTIFREQUENCY RECORDS SHOWING CONDITIONS IN IONOSPHERE, HUANCAYO MAGNETIC OBSERVATORY, PERU. (A) FOR DAY AND FOR NIGHT, AND (B) FOR SUMMER AND WINTER.

Structure changes with time of day and with season of year.



CHANGES IN EARTH'S MAGNETISM AND CESSATION OF RADIO REFLECTIONS FROM IONOSPHERE ACCOMPANYING BRIGHT ERUPTION IN SOLAR CHROMOSPHERE AUGUST 28, 1937.

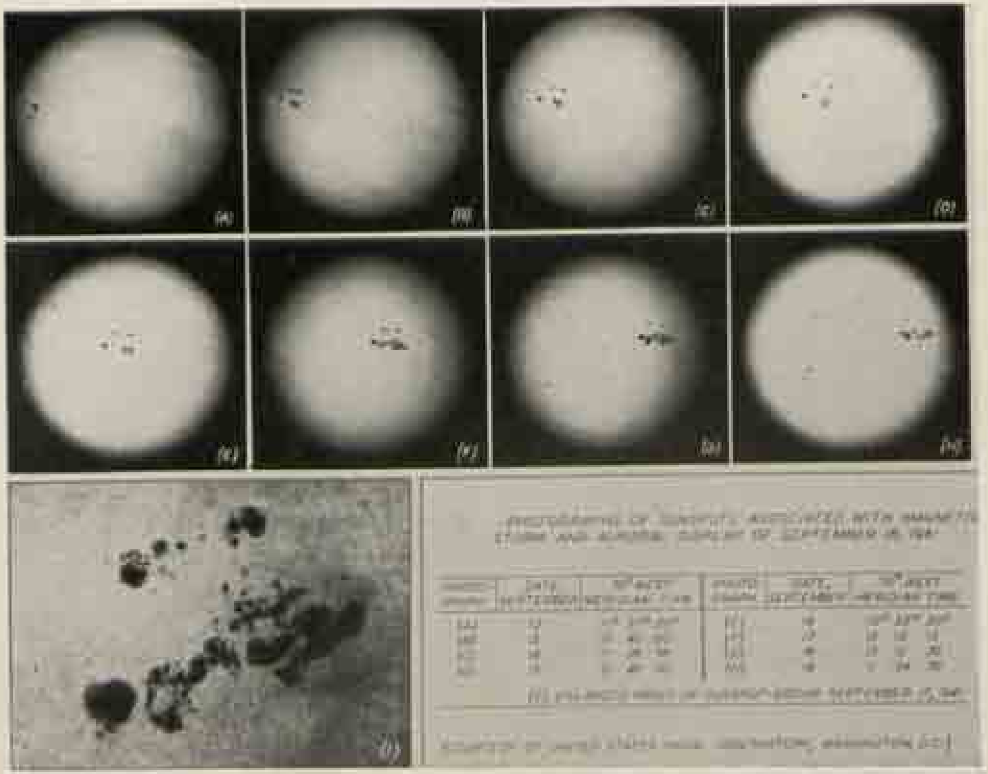


NORMAL AND DISTURBED IONOSPHERE, KENSINGTON (MARYLAND) EXPERIMENTAL STATION.

Disturbance coincides with intense magnetic storm of March 1, 1941.

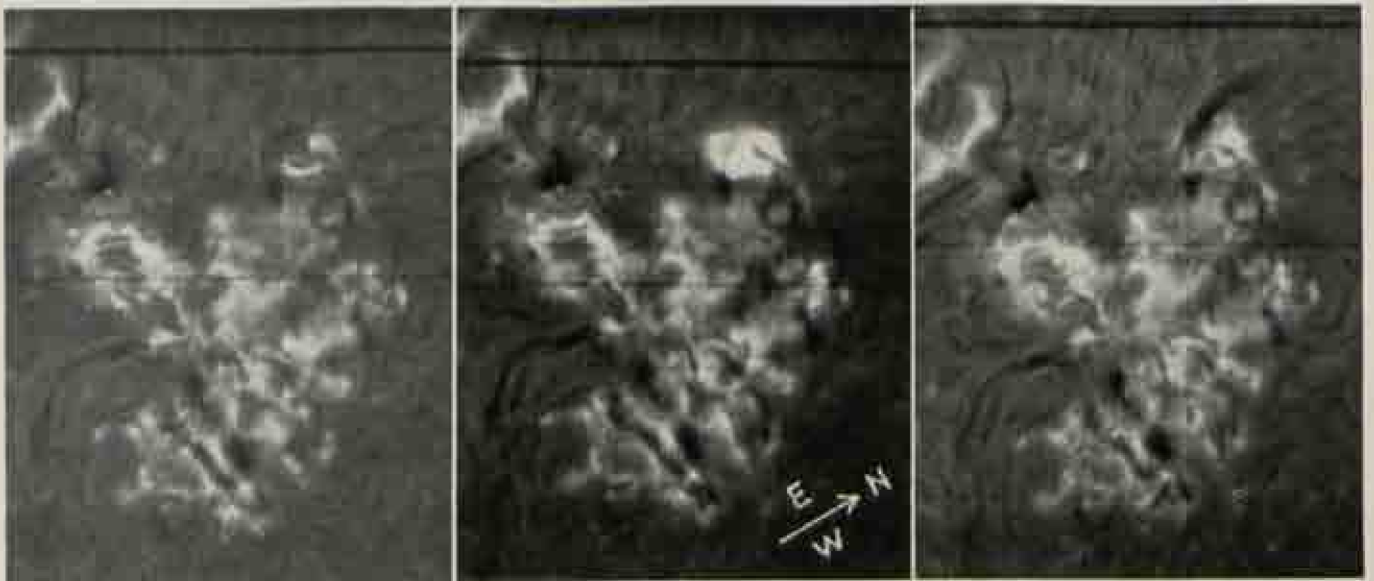
VIEWS FROM THE AIR OF (A) HUANCAYO MAGNETIC OBSERVATORY, PERU, AND (B) COLLEGE MAGNETIC OBSERVATORY, ALASKA.

The Huancayo Magnetic Observatory of the Carnegie Institution of Washington is on the geomagnetic equator at an altitude of 11,000 feet above sea level and was established in 1922; the College Magnetic Observatory of the University of Alaska and the Carnegie Institution of Washington was established in 1941. (Photographs by W. Runcie and Marler Bros.)



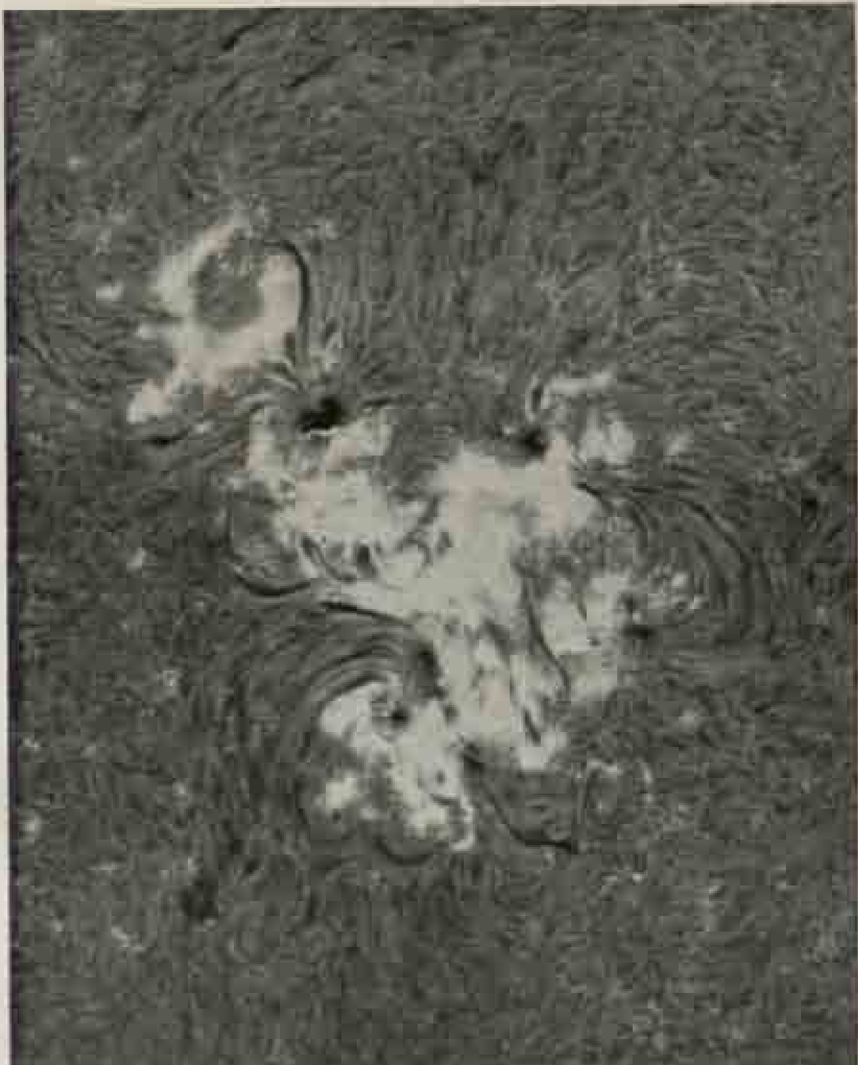
PHOTOGRAPHS OF SUNSPOTS ASSOCIATED WITH GEOMAGNETIC STORM AND AURORAL DISPLAY OF SEPTEMBER 18, 1941

(Courtesy of U. S. Naval Observatory.



HYDROGEN SPECTROHELIOGRAM SHOWING BRIGHT CHROMOSPHERIC ERUPTION OVER SPOT GROUP ASSOCIATED WITH GEOMAGNETIC STORM OF SEPTEMBER 18, 1941.

Exposures taken at 16^h21^m, 16^h26^m, and 16^h36^m when the group was at 11° North in 10° West.
(Courtesy of Mount Wilson Observatory, Carnegie Institution of Washington.)



HIGH-LEVEL HYDROGEN FLOCCULI OVER SUNSPOTS ON SEPTEMBER 16, 1941.

Detailed structure is evidence of extensive fields of force around sunspots. (Photograph by Mount Wilson Observatory, Carnegie Institution of Washington.)

PHOTOGRAPHS OF THE AURORA BOREALIS WHICH ACCOMPANIED THE GEOMAGNETIC STORM OF SEPTEMBER 18, 1941.

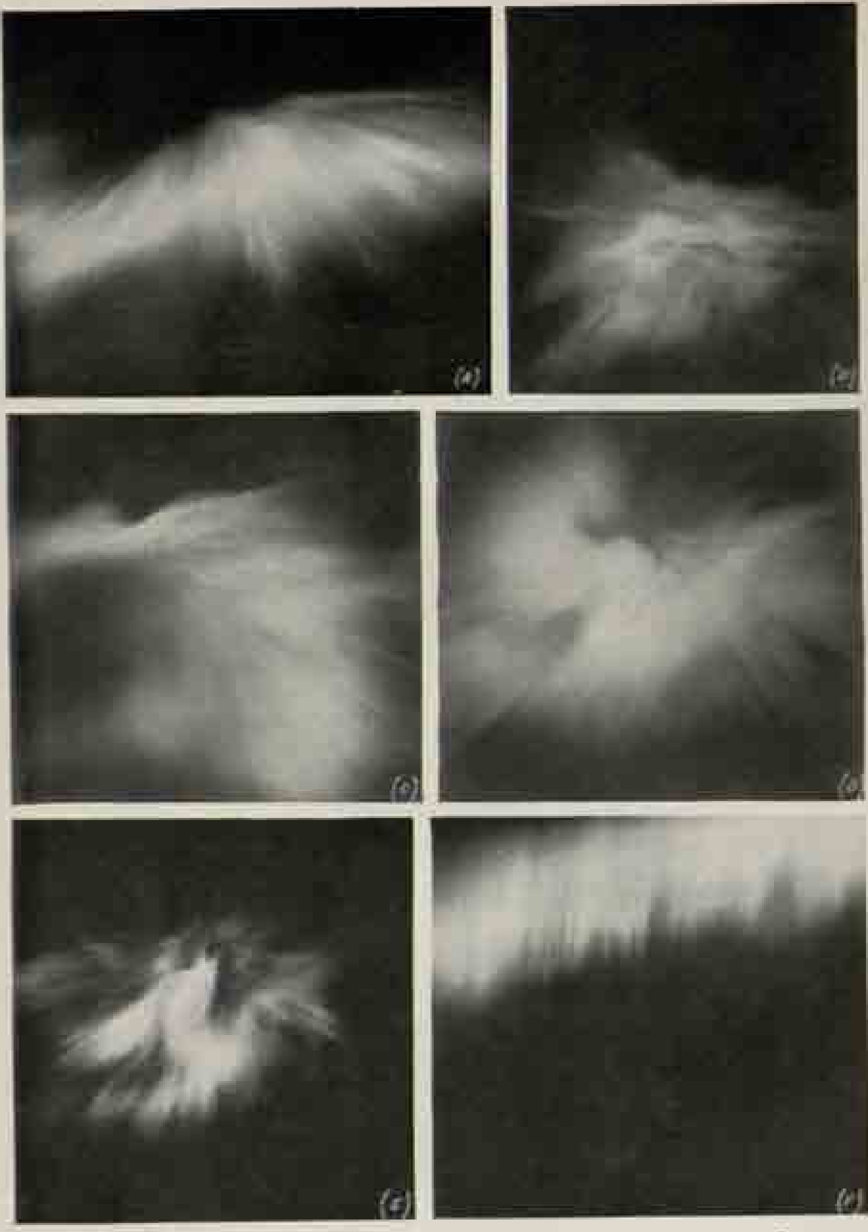
(All times are mean 75° west meridian.)

(A) [illegible], Ithaca, N. Y.; aimed at Pegasus, nearly due east; shows that the rays make the dip angle with respect to the horizon; corona appears to have been located about 17° south of the zenith; exposure 10 seconds. (Photograph by C. W. Gartlein and courtesy of National Geographic Society.) (B) Looking due west from top of Building D, Harvard College Observatory, Cambridge, Mass.; this intense red patch appeared behind a church steeple at 19^h30^m. (Photograph by R. Newton Mayall.) (C) 20^h25^m, Patchogue, N. Y., exposure 16 to 20 seconds. (Photograph by E. Dayton Thorne.) (D) 20^h30^m, Patchogue, N. Y.; exposure 10 to 20 seconds, f/3.5. (Photograph by E. Dayton Thorne.) (E) 20^h40^m, Patchogue, N. Y.; exposure 10 to 20 seconds, f/3.5. (Photograph by E. Dayton Thorne.) (F) Made at Saranac Inn, N. Y.; direction northwest by north; exposure 20 seconds or more. St. Regis Mountain, 10 miles away, attests the intensity of general illumination when this shot was made about midnight. (Photograph by Ernest T. Pearson.)

PHOTOGRAPHS OF THE AURORA BOREALIS WHICH ACCOMPANIED THE GEOMAGNETIC STORM OF SEPTEMBER 18, 1941.

(All times are mean 75° west meridian.)

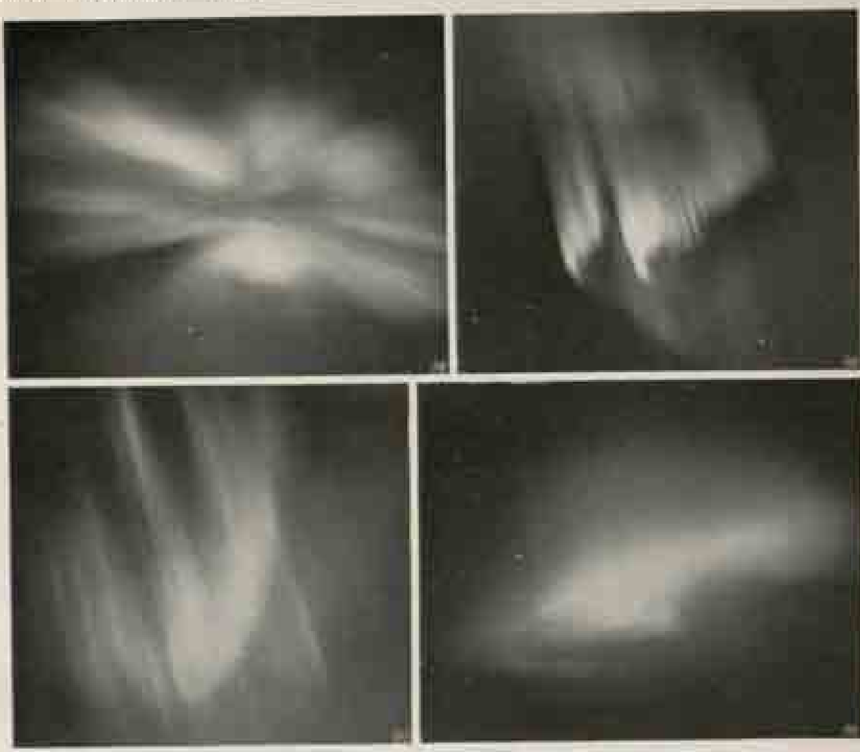
(A) 20^h10^m, Riverhead, Long Island, N. Y.; looking west. (B) 20^h15^m, Riverhead, Long Island, N. Y.; looking south overhead; exposure 30 seconds, f/2. (C) 20^h20^m, Riverhead, Long Island, N. Y.; looking northwest by north; note Big Dipper stars, including Alcor; exposure 30 seconds, f/2. (D) Riverhead, Long Island, N. Y.; looking south overhead; exposure 30 seconds, f/2. (All photographs by Kurt W. Opperman.)



PHOTOGRAPHS OF THE AURORA BOREALIS WHICH ACCOMPANIED THE GEOMAGNETIC STORM OF SEPTEMBER 18, 1941.

(All times are mean 75° west meridian.)

(A) 20h10m, with camera pointed overhead, Patchogue, N. Y.; gorgeous corona, a feature of the display unusual so far south, and auroral light filled southern half of the sky, while the north was quite dark; note Altair in lower center and Delphinus in left center. (Photograph by E. Dayton Thorne.) (B) Caldwell, N. J.; camera pointed about 7°–10° south-southeast of zenith toward coronal center; exposure 5 seconds, f/3.5. (Photograph by R. W. Olsen.) (C) Caldwell, N. J.; same as (B); exposure 10 seconds, f/3.5. (Photograph by R. W. Olsen.) (D) Caldwell, N. J.; same as (C); exposure 10 seconds, f/3.5. (Photograph by R. W. Olsen.) (E) Caldwell, N. J.; same as (D); exposure 10 seconds, f/3.5. (Photograph by R. W. Olsen.) (F) Saranac Inn, N. Y.; curtain toward northwest; color of main body was green with edges red, gold, and purple; exposure about 4–6 seconds. (Photograph by Ernest T. Pearson.)



PHOTOGRAPHS OF THE AURORA BOREALIS WHICH ACCOMPANIED THE GEOMAGNETIC STORM OF SEPTEMBER 18, 1941.

(All times are mean 75° west meridian.)

(*A*) $19^{h}10^{m}$; corona, just south of Vega, was formed by the rayed band shown in (*C*) of this plate and (*A*) of plate 18; exposure 10 seconds. (*B*) $22^{h}50^{m}$; very beautiful rayed band in the northwest; shows very narrow ray-structure which seems to be characteristic of a peak of a display; lower border of rays was red and they were in rather rapid motion; this is a fine drapery; exposure 5 seconds. (*C*) $19^{h}18^{m}$; fine rayed band north of west shows convergence of rays; exposure 5 seconds. (*D*) $01^{h}31^{m}$; arc and horseshoe curves in northwest; bright star at left is Vega; shows the beginning of the main phase of aurora on night before great display, actually the beginning of great display; exposure 30 seconds. (Photographs at Ithaca, N. Y., by C. W. Gartlein and courtesy of National Geographic Society.)

ULTRAVIOLET LIGHT AS A SANITARY AID[1]

By Louis Gershenfeld, B. Sc., P. D., Ph. M., D. Sc.

Professor of Bacteriology and Hygiene, Philadelphia College of Pharmacy and Science

Man always has been interested in keeping healthy. When germs were found to be responsible for the causation of many diseases, various methods were attempted to eliminate these agents detrimental to our health. Of the natural agencies associated with health and cleanliness, sunlight has been regarded by the majority of persons as the most beneficial. The heretic Pharaoh Ikhnaton more than 3,000 years ago insisted that the sun is God and it is the only source of life and goodness. Herodotus, the prominent Egyptian physician, some 500 years later stated that sunlight is required especially for people who need restoration of muscular energy. The use of sunlight as a weapon in the treatment of disease is to be noted and can be traced throughout the ages. After our knowledge concerning bacteria and other microorganisms increased and their relationship with disease was proved, physicians advocated the use of sunlight in many diseases and for the destruction of all organisms.

It was about 65 years ago, in 1877, that Downes and Blunt first showed that sunlight killed bacteria. They demonstrated that exposure of putrescible fluids to direct sunlight in the presence of air would stop all growth. Ten years later, Roux confirmed these findings and showed that anthrax spores were destroyed by exposure to the direct rays of the sun. In 1892, Ward, using natural sunlight, demonstrated by actual tests that the actinic rays were responsible for the destruction of anthrax spores. About the same time and since then various workers reported that ultraviolet light possessed a germicidal effect. In 1903, Barnard and Morgan noted that the germicidal action of sunlight is limited to certain of the sun's rays. Later these same workers, using the spectra of carbon and other artificial sources of light for obtaining ultraviolet rays, were able to kill anthrax spores.

[1] One of the Popular Science Lectures, delivered at the Philadelphia College of Pharmacy and Science during the 1940 Series. Reprinted by permission from The American Journal of Pharmacy, vol. 114, No. 1, January 1942.

Within the past decade the susceptibility of microorganisms to ultraviolet radiation has received renewed attention.

FORMS OF RADIANT ENERGY

What is ultraviolet radiation and what has this to do with sunlight? The visible spectrum was discovered in 1665. This visible spectrum which was thought to be one band of light, colored white, was found to be in reality a combination of many different colors of light. You know what happens when a beam of clear bright sunlight strikes a suitable prism or if you gaze at the rainbow in the sky where Nature performs the experiment, you observe tiny drops of moisture present in the air acting as prisms breaking the white ray of sunlight into many visible colored rays, red, orange, yellow, green, blue, and violet. In addition to these bands of visible radiation there are other rays emanating from the sun which are invisible to the human eye. Some known as infrared rays are invisible, but this radiation is detected by the heat produced. Others spoken of as ultraviolet rays, also are invisible; this form of radiant energy is not detected by any of our senses, although some of the effects produced subsequently may become apparent. These three forms of radiation, one visible and the other two invisible, all emanating from the sun, differ in the lengths of their waves. The ultraviolet rays are the shortest; the visible light rays are longer; and the infrared waves are the longest.

The unit of measurement in microscopy is the micron which is equivalent to 1/25,000th of an inch. Wave lengths of light rays are measured in terms of Ångstrom units. An Ångstrom unit is 1/10,000th of a micron; in 1 inch there are 250 million Ångstrom units. The visible light is subdivided into colors of the spectrum by the energy of different wave lengths of an approximate range from the red, 8000 Ångstrom units, to the violet, 4000 Ångstrom units. To be exact, the longest visible rays, the red, have a length of 7610 Ångstrom units; and the shortest visible rays, the violet, have a length of 3970 Ångstrom units or approximately 1/63,000th of an inch. The infrared rays, which are heat rays, are longer than the red and the ultraviolet rays are shorter than the violet.

ULTRAVIOLET LIGHT

The ultraviolet portion of the spectrum consists of wave lengths which extend from a range of 3970 Ångstrom units to about 1000 Ångstrom units. By passing a beam of ultraviolet light through a quartz prism, this can be subdivided approximately into three divisions, the far ultraviolet rays (1000 to 2000 Ångstrom units), middle ultraviolet (2000 to 3000 Angstrom units), and near ultraviolet (3000

to 4000 Ångstrom units). In another more convenient breakdown, the ultraviolet spectrum is divided into four parts, the divisions or classes being based upon the use of these specific radiations or so divided based upon their principal effects. From 1000 to 2000 Ångstrom units are radiations which form a toxic gas, ozone, the so-called ozone-forming ultraviolet radiations. In the range from 2000 to 2950 Ångstrom units are to be found radiations which are effective in destroying germs. In the range from 2800 to 3300 Ångstrom units are to be found the "biologically effective" radiations, those producing sunburn; and because they also are useful in activation of vitamin D, they sometimes are called the antirachitic ultraviolet radiations. In the range from 3300 to 4000 Ångstrom units or the region closest to the visible spectrum are to be found radiations useful for their fluorescent display and of value in some types of photography. These divisions are not very sharply defined; they frequently merge and often actually overlap considerably. However it is important to note that the chemical and physiological actions of these rays depend upon the length of the waves making up these different radiations.

TRANSMISSION OF ULTRAVIOLET LIGHT

Before considering the value of ultraviolet light as a sanitary tool, there are other considerations which should be directed to your attention. All rays of the sun pass through the atmosphere before they reach the earth. The ordinary atmosphere will allow the passage of infrared rays and the rays of the visible spectrum. Most ultraviolet rays from the sun, however, fail to reach the earth. Actually the air acts as a differential filtering medium holding back many rays. In most places radiations shorter than 2900 Ångstrom units never penetrate to the ground; in fact the shortest to reach us is usually from 2950 to 3100 Ångstrom units in length. Less than 0.1 percent of the total radiations from the sun is in the form of ultraviolet rays and almost all of the latter are longer than 2900 Ångstrom units. Furthermore only the long ultraviolet rays will pass through ordinary window glass. While the latter is transparent to the visible light rays, it is opaque to light of wave lengths shorter than 3100 Ångstrom units. You will note from these observations that sunlight reaching us therefore is most frequently devoid of an active germicidal effect and that is especially the case of sunlight that has passed through an ordinary pane of window glass. On the other hand, a special type of commercial glass, and in particular quartz, allows the passage of ultraviolet light possessing wave lengths shorter than 2900 Ångstrom units. This is of paramount importance in sanatoria and nurseries, where it becomes necessary to use glass of special composition instead of the ordinary window-

pane glass so as to transmit into the interior biologically active rays, and in the manufacture of equipment to be used for an artificial source of ultraviolet light. Furthermore most ultraviolet light is absorbed by thin layers of fluids containing proteins or turbid material, by layers of oil and grease, and also by tissue cells. Tissue is not penetrated more than 1 millimeter (0.039 of an inch) in depth. Very short wave-length radiations are absorbed by air in the production of ozone. These facts must be considered in the practical use of ultraviolet light as a bactericidal agent.

GENERATING ULTRAVIOLET LIGHT

Artificially generated light is just as effective as the corresponding rays of sunlight that possess the same wave lengths or the same intensity. The source of ultraviolet light has very little influence upon the result, providing the wave lengths or intensity are identical. The sun, the natural generator of ultraviolet light, is not always available. Even when available the natural germicidal ultraviolet rays cannot be harnessed conveniently to be supplied to environments not reached by sunlight. It therefore became necessary to provide some means of artificially generating ultraviolet light so as to make it available whenever and wherever needed. When investigators, especially during the past two decades, reported marked destructive effects of different microorganisms by controlled laboratory tests using special artificially generated short wave lengths of ultraviolet light, the latter was hailed as the ideal sterilizing agent and its use was advocated far and wide. As in other similar cases, not recognizing that its application is bounded by distinct limitations, the use of ultraviolet light was soon discarded owing to its abuses, and also to the fact that many of the ultraviolet generators available were not only expensive but produced radiations which were unsuitable as germicidal agents.

RENTSCHLERIZING PROCESS

After several years of careful research and extensive experimental work, Dr. Harvey C. Rentschler, engineer and research director, Dr. Robert F. James, bacteriologist, and other workers associated with Westinghouse Lamp Division succeeded in designing equipment for ultraviolet radiation which is inexpensive and overcomes most of the objections made against other previously introduced ultraviolet generators. The radiations produced by the latter were found to cover broad rather than selective bands of wave lengths, which were found to be most effective as germicidal agents. In many of the generators used previously, an appreciable amount of infrared rays was generated, resulting in the production of high temperatures during operation. Such operation in refrigerated com-

partments was costly and not practical. To keep the heat directly from the material being treated, the generators had to be placed at relatively long distances from them, resulting in a marked decrease in the effectiveness of the shorter and highly germicidal radiations. In other types of generators, there was a large output of high concentrations of ozone and nitrous oxide, which were objectionable, as they affected humans and inanimate objects being treated. The newly introduced equipment or so-called ultraviolet lamps have evolved from a careful segregation of different wave lengths and the elimination of other short-wave radiations that are valueless as bactericidal agents and even undesirable.

By a simple and rapid method for measuring ultraviolet radiation, a better understanding of the action of short waves on germs has become possible. In fact it was found that radiations or short waves generated at the 2537 Ångstrom unit region of the spectrum possessed the greatest sterilizing or germicidal power. The introduction of this new equipment with an effective ultraviolet lamp and the practical application of selective bactericidal ultraviolet waves or radiations developed into a process known by many as the rentschlerizing process or rentschlerization. These terms are taking their place today with the term "pasteurization" named after Pasteur, a process in which moist heat is used to render disease-producing bacteria innocuous.

ULTRAVIOLET LAMPS

Many of you are familiar with or have seen sun lamps or so-called health lamps. These sun lamps generate waves or radiations which vary in length from 2800 to 3200 Ångstrom units. Accordingly they supply only long ultraviolet waves and practically of the same intensity as we get from sunlight under ordinary conditions. In fact the glass used in sun-lamp bulbs will not allow the passage of radiations of wave length shorter than 2800 Ångstrom units. Sun lamps therefore do not transmit ultraviolet radiations which are germicidal.

The effective ultraviolet lamps used today to generate radiations of value for the destruction of bacteria depend upon a carefully planned type of vapor source, emitting controlled and selective bactericidal ultraviolet radiations. They consume a minimum amount of power and radiate a minimum amount of heat energy. They are almost identical in operation with the fluorescent lamp, except that fluorescent powder is absent. As the current flows from electrode to electrode through mercury vapor (to which other gases are frequently added), very little visible light is produced, but most of the output of its energy is concentrated at the 2537 Ångstrom region of the spectrum. At least 80 percent of the radiant energy is crowded into ultraviolet radiation at this region which provides the most effective germi-

cidal effect (2537 Ångstrom units). In the case of a fluorescent lamp, the powder present on the inside is activated and fluorescence is produced. In the case of the ultraviolet lamp, the ultraviolet radiations generated pass through a special type glass used in making the lamps. This glass is purposely chosen as it will allow the passage of the selected waves of ultraviolet radiation of greatest germicidal power and at the same time absorb most of the objectionable ultraviolet wave lengths in the ozone-producing region. The low vapor pressure and low current density in the lamp also reduce to a minimum the radiations emitted in the visible spectrum. Ultraviolet lamps radiate energy of wave length ranging from 2000 to 2800 Ångstrom units and, as mentioned previously, most of the radiations are 2537 Ångstrom units in length. Inasmuch as most of the radiations are not visible, individuals are prone to forget that ultraviolet lamps when operated should not be viewed by unprotected eyes for long periods of time or especially at close range, as a conjunctivitis may develop.

Equipment provided with suitable ultraviolet lamps has been designed to fill practically all needs. These lamps are marketed under different trade names, among the latter being the Sterilamp, Germicidal Lamp, Safe-T-Aire Lamp, and the Saniray. The lamps are designed usually to operate on alternating current through a low-capacity transformer. If only direct current is available, a converter unit is necessary. Several lamps, wired in series, never in parallel, can be operated from one transformer. The lamps are lighted on the turn of the switch. Other than keeping them clean, there is no more attention required than is necessary for an electric bulb. These lamps are available in different sizes for use in all kinds of fixtures, a fixture and ultraviolet lamp being a complete unit in itself. After long use and even at low temperatures, the lamp may show some discoloration, the latter in turn absorbing some of the ultraviolet rays. Ultraviolet lamps have a more effective life when operated at temperatures above 40 degrees F. Under average conditions of use, they will operate for many thousands of hours, giving a continued service for at least 6 months (4,500 hours) before replacement becomes necessary.

SANITIZATION

You are familiar with the term "sterilization" which, speaking broadly, refers to the destruction of every form of life, visible or invisible, harmful or innocuous. The term "germicide," referring to agents which kill germs, is used synonymously with the term "bactericide" signifying only those agents which destroy bacteria. The term "pasteurization," previously mentioned, refers to a process which subjects products affected by heat to temperatures sufficient to destroy

certain germs, especially those producing disease, and to reduce the total numbers of all forms of life present, without damaging the product under treatment. Pasteurization does not kill all germs and accordingly does not effect a complete sterilization.

Ultraviolet light as commonly used does not render materials sterile. The term "sterilization" is used incorrectly when applied to the use of ultraviolet light, since the complete destruction of all forms of life is rarely attained by its application in practice. Furthermore this is never sought, and in fact from a sanitary viewpoint is not necessary. Ultraviolet radiation, when used, is employed to reduce the total germ content and especially for the destruction of those organisms causing disease or capable of decomposing materials. It is not practical to effect complete sterilization. It is on this account that for want of more suitable terms the words "sanitize" and "sanitization" have been advocated in place of sterilization and disinfection. Sanitization is that process which renders materials free of organisms that produce disease, or are capable of decomposing substances, or which are indicative of insanitary conditions. The term describes more satisfactorily the action of ultraviolet radiation and has come into use especially when the latter is employed as a sanitary aid.

FACTORS CONCERNED IN EFFECTIVE RADIATION

There is a variation in the apparent sensitivity to ultraviolet radiation not only by different species of organisms but this variation is found in the same species at different stages of its life cycle. The thickness of a layer of organisms to be radiated and the fact that individuals in a clump may shield others from radiation are to be considered.

The amount of water vapor present has an influence on the effectiveness of ultraviolet radiation. At ordinary room temperatures, much more radiation is required to destroy germs at a high humidity than at a low humidity.

The action of ultraviolet light is practically a surface action. It possesses only very slight penetrative powers. Radiation therefore must reach all surfaces to be effective. In order to maintain proper intensity, lamps should be cleaned, and regular and thorough cleaning of materials and environments wherever practical will be most helpful.

The intensity is influenced by the distance that the surface to be treated may be from the ultraviolet radiations. The distance and the time of exposure are important factors to be considered at all times when using ultraviolet light for the destruction of germs. An indication of what this means is to note that a 30-inch lamp generating mainly 2537 Ångstrom unit wave lengths will kill almost all of the commonly observed non-spore-forming bacteria within 1 minute, when at a distance of 1 foot, but it will require 4 minutes if at a distance of

3 feet. In like manner, radiation of 3000 Ångstrom units will require six times as much energy to be as effective as radiation of 2537 Ångstrom units.

Radiations travel in straight lines. It may therefore be necessary to add reflectors to equipment, but it is important that the reflectors are made of material which will absorb but a minimum amount of the rays. In other instances, especially on exposed foodstuffs, the proper ratio of wave lengths between 1000 to 2000 Ångstrom units present in the lamp will convert the oxygen of the air into ozone. The latter, a germicidal agent, will diffuse and reach areas inaccessible to the radiations. In the concentrations present we do not encounter the objectionable features noted when ozone as the sole effective disinfecting agent must be present in the high concentrations usually required.

In general it can be said that properly designed ultraviolet lamps from which 2537 Ångstrom unit wave lengths radiate are available to be used under conditions as advised by engineers. These lights have been found satisfactory in practice after thousands of experiments. Where special occasions arise it may be advisable to determine beforehand the necessary electrical characteristics and materials of construction required.

The use of properly constructed ultraviolet equipment will supply a tool which will be a valuable sanitary aid. One may work freely within the radiated spaces and experience no ill effects. It is advisable to wear eye shades or shaded glasses when work is to be carried on at close range or for long periods of time. Imperfect control or overdoses will not produce any poisonous byproduct and will not impart toxicity to the substance or material under treatment.

APPLICATION

The use of ultraviolet light of proper intensity, another great scientific achievement, is now available as a practical sanitary aid with widespread applications. Equipment, designed and installed at low cost, can be adapted for a great diversity of uses. It will be impossible to consider in detail the wide opportunities for its many applications and the conditions under which it can be and is used. Important facts, however, will be presented revealing its efficiency in certain fields; and in other instances, attention will be directed merely to many other uses to which this process can be and is being applied.

SCIENTIST'S AERIAL WARFARE

Bacteria and other microorganisms are present in the air and atmosphere. The latter serve as transporting agents to enable the organisms to gain access to a more favorable environment. The kinds and

numbers of microorganisms in the air vary in different environments and in the same environment at different periods, but certain forms are generally present. Molds, yeasts, and spore-bearing bacteria, all of which may be non-disease-producing, are rather common. Air laden with excessive amounts of these organisms may be responsible for the contamination and spoilage of foodstuffs and different products. Most disease-producing bacteria are not found in the air under ordinary conditions as in the home, or in the average working plant. However, under appropriate conditions, especially indoors or in enclosed spaces, disease-producing bacteria may be found in the air of such environments. They may remain viable for considerable periods of time, even drift around in the air currents, and thus constitute a hygienic or sanitary hazard. The elimination of such hazards especially in hospitals and other institutions has been of great concern to everyone.

Workers in all branches of science have been constantly at war with another kind of enemy—small invisible foes that are lurking constantly in the atmosphere. The control of the sanitary quality of the air in environments where foodstuffs and other products are processed or stored, by means of ultraviolet light, which are death rays to these invisible foes, has reduced markedly spoilage losses. This same weapon, made available easily and at all times, has supplied another invaluable tool for the continued battle against those small invisible and undesirable organisms which cause all kinds of scourges and are ever ready to attack us from impenetrable ambuscades.

PRACTICAL AIR SANITATION

Hospitals.—Anyone who is familiar with the history of the beginning of modern aseptic surgical methods will tell you about Lister's technique in which he attacked the problem of bacteria in the air by using a carbolic acid spray before and during operations as a means of killing all, or at least decreasing the content of, the disease-producing bacteria in the atmosphere and thus reducing the number of cases of postoperative infection. Sprays, because of the difficulty of providing practical means of application, however, were not found to be very effective. The introduction of air-filtration processes and modern air-conditioning systems has not proved to be adequate in all instances. These measures, however, aided by ultraviolet light or the latter by itself, applied continuously in operating rooms have resulted in an almost complete elimination of wound contamination from air-borne bacteria. This changed condition has brought about an improvement in clinical results that is agreeably surprising. Wound healing has been more rapid and with less reactions. The general postoperative condition of patients has shown marked improvement. The fatality rate has been cut in half through the elim-

ination of cases of severe wound infection which was frequently fatal. In operating rooms where ultraviolet light is properly installed, the greatest amount of air in such rooms comes under the continuous direct action of the rays. Sterilized instruments and other equipment, dressings, bandages, and other materials can be kept sterile by continuous ultraviolet irradiation of the air in contact with such materials. This method is used in hospitals, in the private offices of physicians and dentists, by barbers and beauticians, and others.

In nurseries, in cubicles, in children's wards, better air sanitation and reduced risk of cross infections have resulted from the use of ultraviolet light. In many instances, the ultraviolet rays have been properly placed across the entrance to each cubicle or small room. Such a barrier or curtain of ultraviolet light has aided in preventing the spread of air-borne bacteria. Properly engineered installations will mean normal and comfortable air currents free of disease-producing bacteria, which will pass through doorways or corridors or from ward to ward, and will eliminate the danger of cross infection or of transporting infectious organisms from one patient to another.

Not so many years ago, fumigation was a commonly practiced procedure. Rooms and other quarters which had been occupied by patients with contagious diseases were treated with formaldehyde and other suitable gases, but this method as a sanitary aid was discontinued because of its inefficacy. Other techniques for the disinfection of such environments have been used, but all of them are costly or time consuming, or there are other reasons for seeking a more satisfactory procedure. Ultraviolet irradiation is being used in various contagious-disease hospitals as a valuable aid in the preparation of hospital rooms, not only to reduce the length of time of preparation and thereby increase the length of time of occupancy, but also to prepare rooms with an atmosphere low in the content of bacteria and certainly lower than was previously possible.

Hospitals are experimenting with ultraviolet irradiation in quarters other than mentioned above, as in kitchens, on conveyors holding food trays, in corridors, waiting rooms, clinic rooms, dispensaries, examining rooms, incubator rooms, nurseries, isolation wards, etc. The experience of the management in the foregoing will make available in the near future more data concerning this valuable sanitary safeguard. There are some physicians and dentists who are using ultraviolet irradiation in the waiting rooms of their private offices. Solaria, children's homes, and other institutions also are utilizing this new tool.

Air-conditioning systems.—Modern air-conditioning systems provide air which is at the proper humidity and desired temperature, is practically free of dust and dirt, and is low in its bacterial content. In these systems there usually is a recirculation of the air in the

quarters supplied. Most of this recirculated air before treatment is contaminated with bacteria. The proper installation of ultraviolet radiation in air-conditioning ducts is practiced commercially for the destruction of bacteria. By this method nothing is added to the air nor is anything which is desirable removed. Not only office, apartment, and other buildings, but many railroads are now using ultraviolet irradiation in combination with air-conditioning units so as to control better the sanitary quality of the air supplied. This supplement perfects air conditioning, for air sanitation joins the physical comforts offered by the latter. We can expect more and more stores, theaters, restaurants, other public places, and private homes to have this new type of installation added to their quarters.

Manufacturing plants and testing laboratories.—In pharmaceutical, chemical, and biological laboratories where in the manufacture of various preparations, especially serums, vaccines, and other sterile medicaments, it is important to obtain a sterile end product for marketable purposes, ultraviolet rays employed during all or many of the stages of processing such preparations, by eliminating air borne bacteria, have proved to be a valuable aid in avoiding possible contamination. In the preparation of ointments, cosmetics, and other pharmaceuticals, the keeping qualities of these preparations are reduced and losses result because of spoilage due to the development of fermentations by yeasts and other bacteria or by growths of molds and fungi. The use of ultraviolet irradiation to maintain bacteria- and mold-free conditions in the air during the processing and at the same time wherever possible to sterilize the surfaces of jars and other containers subject to contamination has resulted in prolonging the life of these preparations.

In testing laboratories, where all kinds of materials are examined to determine whether they are sterile or to note the bacterial content, it is most important that all precautions be taken to eliminate contamination during the period when the materials are removed for the tests to be made and subsequently when examinations are conducted. Aseptic conditions throughout are absolutely essential. Airborne contamination is the dread of all workers who do culturing and conduct other bacteriological examinations. The use of selected ultraviolet radiations is a valuable addition in combating possible contamination during such testing. Suitable equipment has been designed for a portable ultraviolet unit which can be moved easily at will to any quarter and irradiate effectively areas of definite cubic contents.

SANITATION IN THE FOOD AND BEVERAGE INDUSTRIES

A large number of installations of suitable equipment radiating the selective bands of ultraviolet rays have been in operation in all kinds of food establishments and bottling plants and have demonstrated their effectiveness and value. Important considerations are presented.

Meat industry.—Fresh meat composed of nutritive substances and approximately 80 percent water, an ideal environment for bacterial and mold growths, will spoil unless it is kept properly. The commonly practiced method of preservation is to place such meats under suitable refrigeration or to keep them in properly operated cold-storage plants. But even under the most ideal conditions, physical and chemical changes occur. Evaporation occurs and there is a material shrinkage, resulting in a reduction in weight which frequently is an appreciable percentage loss. Certain types of bacteria and molds develop even at the low temperatures used. They produce slime and coatings which affect the odor and flavor and cause a change of the natural color. It therefore becomes necessary to trim the meat and to wash and clean the surfaces to remove the growths and avoid an impairment in flavor, color, and odor. The resultant financial losses are self-evident. The presence in walk-in refrigerators, cold-storage rooms, display boxes and cabinets of properly installed equipment radiating the selective bactericidal ultraviolet light and containing low concentrations of ozone (not more than 0.1 percent) has provided a means of reducing the losses and making available more satisfactory and more salable meats for human consumption. Irradiation is said to produce a very slight surface coagulation which does not affect the color, taste, or odor, but it does cause a reduction in the evaporation and subsequent shrinkage. Some workers claim that ultraviolet light as commonly used does not coagulate the surface of the meat, but admit that owing to the sterilizing effect, an additional saving results. The humidity can be increased in the cold environment to 85 or 90 percent, whereas in the cold-storage systems in present-day service without irradiation, it ranges from 60 to 75 percent. The properly engineered installations provide for the destruction of bacteria and molds not only on the surface of the meats but in all parts of the cooler including the air, ceiling, walls, etc. The reduction of bacterial and mold growths reduces to a minimum the necessity of trimming, and especially deep trimming, with its resultant waste, and the production of bad odors, flavors, and objectionable appearances. Ultraviolet light properly used for meat, whether in the large walk-in refrigerator, the refrigerated freight car, the small cooler, or the refrigerated display case or cabinet, will produce an all-round better and more sanitary product, and obviously at a reduced cost.

The Tenderay Process, developed by workers at The Mellon Institute, which has for its purpose the tenderizing of meat, utilizes ultraviolet light for inhibiting mold and bacterial growth as an essential part of its operation.

Baking and dairy industries.—The bugaboo in the baking plant is mold growth. Throughout the entire processing conditions are ideal for the development and proliferation of molds of all kinds and objectionable yeasts. In the marketing of the finished product, whether bread or cakes, you have in most instances fresh moist nutritive materials which also lend themselves for the development of objectionable yeasts and molds from yeast and mold spores in the air and from other sources which may find their way in or on the bread or cakes. Many of the large baking establishments were among the first to introduce ultraviolet radiation in their plants. Their products are kept under the protecting rays coming from suitably installed equipment throughout the entire processing and especially from the moment they leave the oven until they are packaged. Conveying, cooling, slicing, and wrapping are conducted under proper irradiation, which even renders wrapping material free of contamination by undesirable yeasts, molds, and bacteria. Not only are the air and the plant equipment that comes in contact with the product continuously irradiated, but the destruction of undesirable yeasts and molds on nuts, raisins, and other ingredients added to bread and cakes is effected by treatment with ultraviolet light. This important sanitary aid has improved the keeping qualities of these products so that they can be kept in a safe and usable condition for longer periods of time in the usual channels of distribution and after they reach the consumer.

Many uses of ultraviolet irradiation have evolved and are evolving in the dairy industry. Its use in dairy barns for keeping sterile dairy equipment during storage, and in plants proper in the storage and cooling rooms, in vats and coolers, in storage and tank trucks, and over milk-bottle conveyors to insure freedom from contamination after the bottles leave the washing and sterilizing machines until they are filled with the milk has resulted in a marked reduction in contamination. Similar reduction and resultant financial savings have been effected in the processing and packaging of butter, cheese, and other dairy products.

Other foods and beverages.—Ultraviolet light is being used as a sanitary aid on the farm in poultry houses and in incubator rooms. In the marketing of preserves, when glasses and other containers of jellies and jams are allowed to cool before they are capped, contamination and subsequent spoilage may occur. The use of irradiation during the cooling operation eliminates contamination to a large extent. Similar application is made in food plants marketing salad dressings, in the frozen-food industry where fruits, vegetables, fish,

and other products are treated with ultraviolet light before they are frozen, and in the packing and storage of fruits and vegetables, the latter being passed under a bank of effective rays and then wrapped or packed or stored in an environment where the rays are present.

The beverage industry also is utilizing this new sanitary aid. Bacteria and molds may affect the flavor, odor, and appearance of bottled drinks. To eliminate such contamination or at least to keep these objectionable invaders at a minimum content, ultraviolet light is being used in the syrup vats and other tanks, over the bottle conveyors, for treatment of bottle caps and stoppers, and throughout the plant in general. A possible future application of this process is in the brewing and fermentation industries. In the manufacture of beer, wine, and other alcoholic beverages, there are many opportunities for possible contamination by bacteria, undesirable yeasts and molds, resulting in the production of objectionable products. The use of this sanitary tool will undoubtedly be helpful here in reducing spoilage losses.

SANITATION OF DRINKING AND EATING UTENSILS

Proper sanitation is necessary in establishments serving foods and drinks to the public. One of the great dangers in such places is the possibility of becoming infected with disease-producing organisms from a common drinking vessel or from utensils not cleansed and sterilized properly.

The first law passed in the United States against the common eating and drinking utensil was in 1909 when in Kansas legislation was adopted prohibiting the use of the common drinking cup. The use of the common drinking and eating utensil is dangerous and undoubtedly is a source of the spread of infectious diseases as it serves as a vehicle for the transfer of saliva. Unfortunately the common drinking glass still survives in some offices, factories, public and semipublic places and in other establishments where people are working or are found and where water is consumed. The use of either a common eating utensil or, what is as dangerous, improperly cleansed drinking and eating utensils, adds greatly to the opportunity for the transfer of saliva with all the health hazards that such exchange implies. Particularly during the last few decades has the danger become even greater owing to frequency of travel and the tremendous increase in the number of cafeterias, restaurants, taverns, roadside stands, diners, lunch rooms, bars, luncheonettes, and soda fountains. Improved methods of washing dishes and drinking and eating utensils and the use, wherever possible, of individual sanitary paper service will be necessary to keep down to a minimum the exchange of mouth secretions which is entirely too frequent. Many laws and numerous regulatory measures which have the force of law have been passed in the form of

municipal or township ordinances, county or State laws or acts, or other legislative statutes. Usually the health departments and occasionally other executive branches are responsible for the enforcement of these regulations. In many instances such regulations are nonexistent. In others, the existing laws are inadequate to meet modern conditions or are impractical of enforcement. Frequently we find that there is no attempt made to enforce adequate legislation. What is even as important is the fact that there is comparatively little uniformity in the methods advocated for cleansing and sterilizing drinking and eating utensils. There is a great diversity of recommended practices which should be corrected. In the use of hot water and chemicals for the sterilization of glassware and other eating utensils many problems are encountered especially when operating on a small scale. The maintenance of the proper and effective sterilizing temperatures, the use of chemical solutions which can be kept at adequate strength, the elimination of discomfort to operators in working with chemicals or with hot solutions, the elimination of odors and steam, and the reduction of breakage are some of the features to be considered in any practical process. The use of ultraviolet light may help to solve this problem and the introduction of suitable equipment low in cost will undoubtedly provide a satisfactory means of seeing that all eating utensils will be kept up to proper sanitary requirements.

As a direct development of the scientifically proved value of selected rays of ultraviolet light, eating and drinking utensils after proper cleansing and drying are being sanitized with this outstanding scientific discovery. The effectiveness of the rays for this purpose is dependent on their proper application. Glasses, knives, forks, spoons, and other equipment to be sanitized must be treated in such a manner that all surfaces (inside and outside) are exposed, directly or by direct reflection, to 2537 Ångstrom unit rays for a sufficient period of time and at as short a distance from the source of the rays as physical limitations will allow. Properly applied, the time required is but a few minutes to be assured that all disease-producing bacteria have been killed. In this period of time, practically all disease-producing bacteria and more than 99 percent of the total number of bacteria present, are destroyed. An additional valuable feature is that irradiation can be and is employed to maintain the sanitary condition of the utensils until required for use. You have seen glasses, dishes, knives, forks, spoons, and other eating utensils, after cleansing, being stored on shelves or in compartments or cabinets. During such ordinary storage the equipment is not protected generally from air-borne infection or from contact with dust, flies, and other possible means of contamination, especially after being handled by waiters and others who in picking up one or more utensils, frequently touch others. Ultraviolet light, an efficient dry

sanitizing process, also makes possible an effective dry sanitary storage at all times.

Various manually operated equipment and, of greater convenience, mechanically operated equipment is available for sanitizing eating and drinking utensils and keeping them sanitized until ready for use. Cabinets easy to install and operate are marketed in many attractive designs of different capacities, shapes, sizes, and colors, and they are equipped with direct and properly reflected selected ultraviolet rays. They operate automatically, so that each utensil receives radiation for a definite period and on removal the current is automatically disconnected. These units are very effective and perform their function of sanitization more rapidly than other methods. They are adapted for use not only for large-scale but especially for small-scale operation at soda fountains, bars, and all places where beverages are served; and here the cabinets provide an attractive appearance as well as visual evidence of a safe and effective sanitization procedure.

OTHER APPLICATIONS

Ultraviolet lamps have been installed and ultraviolet radiation is being employed for the sanitization of many different materials and environments. In hotels and in public and semipublic places, this treatment is being applied to the sanitization of toilet seats. The unit is so constructed that after each use the seat is automatically raised into a cabinet containing ultraviolet equipment and it is subjected to ultraviolet radiation. Properly constructed cabinets are in use for the sanitization of hair and shaving brushes, combs, tooth brushes, and instruments and equipment used by physicians, dentists, chiropodists, barbers, and beauticians.

Though previously mentioned, it is of sufficient importance to direct your attention again to the fact that ultraviolet light does not possess deep penetrating powers, and furthermore, a direct hit on the germs by the proper ray is necessary to kill them. All equipment therefore must be built and installed in a manner that will permit the proper sanitizing ultraviolet rays to reach all surfaces of the materials and objects being treated. Unless this is accomplished, ultraviolet irradiation will be uncertain and its value ineffective.

AN ENLIGHTENED PUBLIC OPINION

Your attention has been directed to the foregoing data because it is important that each individual understand something concerning the elements of disease control and understand better the problems facing health workers. The scope of preventive medicine is ever

widening. New sanitary aids and more effective methods are being developed continuously for the prevention of many diseases and to rid materials of infective agents and environments of insanitary conditions. Your familiarity with the data presented will help to form an enlightened public opinion. An enlightened public consciousness in all that concerns the well-being of the everyday citizen, fortified by a familiarity with important measures that can be used to promote public health, will necessarily result in a greater utilization of these sanitary aids and a more widespread introduction of proper sanitary practice.

TRENDS IN PETROLEUM GEOLOGY[1]

By A. I. Levorsen

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The oil industry, like other great American industries, has made effective use of the most advanced thinking in many scientific fields. This is particularly true of its applications of physics, chemistry, engineering, and geology. As a matter of fact, the steep upward curve of the expansion of the industry during the past quarter century merely reflects the increasing use of the sciences in the discovery, drilling, producing, refining, and transporting operations. And, of the sciences that have been employed, none has had a more spectacular rise in usefulness than geology and its close relative, geophysics.

The oil industry differs from most other industries that use the mineral deposits of the earth in one important respect, however, in that its supplies must continue to be replaced by new discoveries. Whereas in the field of coal the supply for generations to come has been discovered, is proved, and is known, the situation in oil is quite the reverse. The oil that our children will use is not yet discovered—and being undiscovered, its location, quantity, and nature are not known. This situation is largely the result of the economic cycle of supply and demand—as the supply increases, the price goes down, and the incentive to discover new supplies wanes. Equilibrium seems to be reached, on the average, when the known reserves are kept at approximately 15 times the current yearly demand—a demand that completely consumes the supply and leaves no residue with which to cushion an emergency. The gas tank of this modern engine of progress must, therefore, be continually replenished and as long as this condition prevails there will be a need for methods and techniques of discovery.

There is now an estimated known reserve of 18 to 20 billion barrels of oil underground—oil which has been discovered, is blocked out, and is available for use. This quantity is adequate only if new discoveries can be made to replace it as it is produced and consumed. The past ability of the industry to maintain discovery has been

[1] Read at the Fiftieth Anniversary Celebration of the University of Chicago, September 1941. Reprinted by permission from Economic Geology, vol. 36, November 1941.

essential to its growth, and if it should fail to find new supplies, it would quickly relapse into a stifling routine operation and gradually stagnate.

The primary work of the petroleum geologist is in the field of oil discovery. His work is, therefore, fundamental and of vital importance, not only to the economy of the industry, but of the nation as well, for oil has certainly become one of the necessities of well-being for this age. He does many other kinds of work within the industry, particularly in the scouting, leasing, and production departments, but failing of discovery, they would all be of little value, for everything he does is subordinate to his function in the maintenance of supplies of crude oil.

Probably as good a measure as any of the role of science in the discovery process is to be found in the most recent of the annual surveys made by Lahee [3] of the basis upon which wildcat well locations were made in 1940. During this year he finds that of the 3,038 wildcat wells drilled, 2,051, or approximately two-thirds, were drilled because of geological and geophysical reasons, and of the remaining one-third, most were drilled for various nontechnical reasons and part for unknown reasons. Moreover, he finds that of the wells drilled on technical advice, 15.6 percent were producers as against only 4.2 percent successful in the case of wells drilled for nontechnical reasons. It was, therefore, nearly four times as advantageous to use technical reasons for making wildcat locations as to use nontechnical reasons.

One of the curious situations in petroleum geology is that in spite of our theories, and of all the workers who have given thought to the problem, little is known of the origin of oil, how it migrates, or how it accumulates. About all that is known is that it is now found in traps of various kinds, and as a consequence, almost the entire geological effort toward discovery consists in the search for such traps. The most obvious trap is an up-fold or deformation of the earth's strata which will keep the oil within the affected area. In the idiom of the profession, these are called "structures" and a pool which produces from such an anomaly is called a "structural pool."

Less obvious and much more difficult to find are those traps that result from a variation in the porosity or in the stratigraphy of the reservoir rock. Pools producing from such situations are called "stratigraphic" pools. Random drilling has been particularly adapted to the discovery of "stratigraphic" pools, for in them we find no guiding surface or shallow indications. Most of the oil fields of the great producing areas of Ohio, Pennsylvania, West

[3] Lahee, F. H., Wildcat drilling in 1940. Bull. Amer. Assoc. Petrol. Geol., vol. 25, pp. 997–1003, June 1941.

Virginia, and Indiana, together with those within the Pennsylvanian sediments of the mid-continent region, are of the stratigraphic type and were discovered largely by the early "wildcatter" who followed whatever hunch seemed best to fit the occasion. Such drilling was totally unscientific but because there were so many shallow stratigraphic pools to discover, it was effective, and many fortunes were built and large quantities of oil were found.

The approach of the petroleum geologist to the problem of finding traps that might contain oil has been chiefly through his ability to locate favorable structural areas, either by surface or subsurface geology, or by geophysical methods. However, as he is forced to search deeper and deeper for his data, and as it is becoming more difficult to find untested "structures," the expense keeps mounting, and he is gradually turning his attention to the possibilities of finding stratigraphic type pools. The ammunition he brings into use for such work includes the microscope, the electric log, paleogeology, paleogeography, imagination, and speculative reasoning based on sound fundamental geological concepts. The tide of exploratory thinking is running strongly in this direction at present, and the possibilities for success are almost unbelievably great.

Probably the most important development of the past decade, and an approach that is still in its infancy, is the continually widening use being made of well cuttings, cores, electrical logs, and all sorts of detailed stratigraphic data. It calls for a technique which, in part, was forced upon the petroleum geologist when drilling methods changed from the use of cable tools to the use of rotary equipment. At that time the driller was unable to make a satisfactory log of the well he was drilling and the geologist was called on to do it for him. This he did through the use of the microscope, and the resulting additions to our knowledge of the stratigraphy, sedimentation, geologic history, paleontology, and structure in much of the sedimentary area of the United States is so vast as to make almost all previous data obsolete and insignificant.

Not only do detailed stratigraphic and sedimentation studies furnish the background for modern subsurface work, but they are also the basis for any scientific search for pools of the stratigraphic type. The operator attempting to find such a pool with a minimum of drilling is indeed sorely in need of geologic assistance. In a way it is like the children's game of Hide the Button, the difference being that the operator now expects the skilled sedimentationist and micropaleontologist to tell him when he is getting "hot" or when he is getting "cold."

In discussing this question of the trend of petroleum geology with one of the geologists of the Gulf coast region, I could not help but agree with him when he stated that, in his opinion, the trend could

be expressed in one word and that word was "downward." He went on to explain that he did not mean that we were going into a decline, but that the thought and the effort of the petroleum geologist were more and more being concentrated below the surface and in the realms of subsurface sedimentation, subsurface stratigraphy, and subsurface paleontology. This entire subsurface development stems directly from the place microscopic methods have taken as a technique of petroleum geology. A person working with subsurface geology began with the terms of the well drillers—"hard rock," "soft rock," "mud," "slate," and the like. Gradually he was able to change those to terms with a more geological sound—limestone, sandstone, and shale, and, as a further refinement, added such general textural and qualifying terms as crystalline, dense, lithographic, porous, sandy, dolomitic, calcareous, and argillaceous. Now, we find him beginning to examine microscopically the individual mineral grains and to reduce their primary characteristics to the simplest possible terms; we find him concerned deeply with slight changes in facies; and we find he is beginning to look into the possibilities of distinguishing the variations of single minerals as a guide to the sedimentary environments of deposition. Some think it is deplorable, but it is nevertheless true in petroleum geology, that the microscope has pretty well supplanted the plane table and stadia rod as the leading method of obtaining geologic data.

Geophysical methods have become so well established in the oil-finding technique as to have long since passed beyond the trend stage. Moreover, it is not the purpose of this discussion to go into other than the strictly geological aspects of petroleum exploration, leaving to others the telling of the brilliant contribution geophysics is making to the oil industry.

The chief function of geophysics in petroleum exploration is to obtain structural data in advance of drilling. Geophysical data, in order to be effective, require geological interpretation and so far this has been successful only in the search for structural accumulations. The time will certainly come, however, when the geologist will be able to interpret geophysical data in terms of sedimentation and stratigraphy and then the entire field of stratigraphic type oil pools will be opened to geophysical methods. Since geophysical data are all below the surface of the ground, when they are added to the steady stream of subsurface well data, they further tend to push our thinking deeper and deeper. Even now the commercially accurate mapping of geologic conditions 5, 10, or even more thousands of feet underground is a daily routine in many areas.

As the exploratory effort becomes deeper, it becomes more complex, and it also increases rapidly in cost. There is a tendency, therefore, in some quarters to go back to a reinterpretation of surface and sub-

surface information for the reason that many of the discoveries of the past, which have been attributed altogether to geophysical methods, would or could have been made by ordinary geological techniques at a much lesser cost.

Obviously, there is much yet to be learned from surface mapping. One important factor is the availability of aerial photographs in nearly all regions, which force into the discard the methods and standards of accuracy that prevailed even a decade ago. Another factor, which has been the cause of many failures of interpretation, is the almost universal presence of unconformities. When a surface fold is projected through two or three unconformities, one or more of which is associated with diverging thickness of sediments, the expression of the fold at the surface has but a faint resemblance to what is found at 5 or 10 thousand feet below it. A third factor that applies to surface geology is that most of the early work was solely concerned with a search for anticlines and other types of favorable deformation. Many regions are therefore being reworked and the detailed stratigraphic information, which was neglected in the first surveys, is now being added. In my own experience, I well know that the year I spent in mapping "structures" in the San Juan Basin of New Mexico could be repeated to better advantage by mapping the stratigraphy and its relation to possible oil accumulation.

This brings us to another trend which is apparent, and that is a growing awareness of the importance of geologic history in the search for new oil fields and new oil provinces. It is expressed in the deep interest of geologists in unconformities, overlaps, wedge belts of porosity, paleogeology, lateral and vertical gradation of porosity and permeability, facies changes, and in all of the varied phenomena of sedimentation. We may think of the rocks between each regional unconformity as being in layers of geology—each layer having its own peculiarities of sedimentation, structure, stratigraphy, and value as a potential oil-producing unit. In some regions, notably west Texas and northern Louisiana, as many as four such layers are being explored and each found productive. Many other developed areas have shown two or three such separate and distinct layers of geology, and we may, therefore, conclude that much of the unexplored territory of the United States, undeveloped because it was thought to be uninteresting and monotonously uniform from a shallow structural viewpoint, now takes on value, because it likewise may be underlain by two or more additional layers of geology. Thus, the first clues to the possibilities of a new region may not appear until one starts exploring 5, 6, or 8 thousand feet below the surface, and thinking through one, two, or three regional unconformities. The almost infinite number of combinations of structure and stratigraphy that have in the past been found to produce oil, if projected into the

future and considered as possibilities of accumulation in each or any of these unexplored layers of geology, reveals a correspondingly large undiscovered future oil reserve and the enormous geologic effort necessary to find it.

Most petroleum geologists began working in two dimensions—length and breadth at the surface. Later, as more wells were drilled, a third dimension, depth, was added. They now find themselves thinking and applying a fourth dimension to their work—geologic time—and as with the other dimensions, its addition to their kit gives the horizon yet another push outward.

The only really new approach to the problem of oil discovery that has developed in many years is the recent use of earth-chemistry or geochemistry. Its approach differs from geological and geophysical systems because it is a direct method, dependent only on the presence of oil regardless of the kind of trap, whereas the older methods are all concerned solely with the search for favorable structure, in which it is hoped oil may be found.

Many claims have been made for geochemical methods and if they were all realized it would be but a short time until all of the oil fields in the world were found. However, there are many geological objections to its philosophy, and so far there have been very few or no oil fields found as the sole result of its application. Until it proves itself to be successful, it will probably continue to be regarded with a considerable amount of restraint as an instrument of discovery. We should not forget, however, that much highly intelligent experimentation and research is going on continually in this field, and that we may well see the day when it, or some modification of the present method, is a generally accepted tool of oil exploration.

A development in petroleum geology, which I believe is significant, is of a different nature since it deals with the geologist rather than with his thinking. It is the trend in the oil industry to place geologically trained and experienced men in executive and managerial positions. It is coming on at an ever-accelerating pace and in nearly every month that passes we hear reports of promotions and changes in which geologists are advanced into positions of authority outside their normal field of activity. As Pratt[3] has so well put it, the geologist now "permeates the industry," and he has come in "like a metasomatic phenomenon in ore deposits in which the invading solution completely changes the internal character without changing the outward appearance."

This trend has far-reaching consequences. Although in the early days the petroleum geologist was practically limited in his application of geology to discovery by his ability to make the nontechnical execu-

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[3] Pratt, Wallace, Geology in the petroleum industry. Bull. Amer. Assoc. Petrol. Geol., vol. 24, pp. 1209–1218, July 1940.

tive understand what he was trying to do, now he finds a more tolerant and understanding attitude in the executive departments, which leaves him more freedom to concentrate on his geology without the necessity of promoting it or selling it to someone with no conception of its philosophy or method. Nothing cools the enthusiasm of a scientist as quickly as an unsympathetic superior, and this handicap, which has prevailed in too many instances, is rapidly being lifted to the ultimate good of both the industry and the science.

Not only is the geologist going into executive positions within the larger units of the industry, but he is also going into the oil business for himself in continually increasing numbers. He may call himself a consulting geologist, but more often than not he is buying and selling oil and gas leases, drilling wildcat wells, and has oil or gas production of his own. The study of geology and its method of thinking is good training for anyone entering the oil industry in a similar manner to the study of law, which has long been considered a good background for entry into business in general.

DeGolyer [4] has pointed out another significant change in the work of the petroleum geologist in that he is becoming more and more a coordinator of a variety of geologic data, all of which are obtained by experts and turned over to him for interpretation. This contrasts strongly with the older methods, where the geologist went into the field himself to get the data, and returning to his office, made his interpretation. Then, one geologist did all of the geological work incident to the drilling of a wildcat well; now there may be a dozen or more specialists, each securing data of various kinds, which are put together by the office geologist into a coherent and related whole. Thus today the exploration problem is complex and the high costs prior to drilling a wildcat well may even approach the cost of the well itself. If one is to succeed at this kind of interpretive geology, the need for the best possible training is obvious.

One of the healthy signs in petroleum geology, therefore, is the interest that is being shown in the college curricula of geology departments. This was aptly put by a petroleum geologist the other day when he said, in discussing one of his college professors, "I worship the very ground he walks on, but he is teaching 10 years behind the times. Something ought to be done about it."

Well, something is being done about it. After studying all of the college catalogs of geology curricula and after sending out many questionnaires, a committee of interested geologists appointed by Henry Ley, President of the American Association of Petroleum

[4] DeGolyer, E., Future position of petroleum geology in the oil industry. Bull. Amer. Assoc. Petrol. Geol., vol. 24, pp. 1389–1399, August 1940.

Geologists, have made a preliminary report.[8] In it they concluded, in part, that more attention in college training should be given to English composition, mathematics, chemistry, physics, descriptive geometry, logic or the ability to reason accurately, foreign language, sedimentation, geophysics, and field work. Biology might well be added to such a list also. Apparently the teaching of the strictly geological subjects meets their approval but they feel there should be more training in the fundamentals of science in what might be called "background" studies. They also favored more problem courses and fewer memory studies in the preparation for a career as a petroleum geologist. In order to do all this and still have time to do the essential work in geology, they believe the standard course of study should be for a term of 5 years, instead of 4, as at present.

I rather think this interest in college curricula is traceable to the general broadening of the viewpoint of the petroleum geologist. As he takes a more active and responsible part in the oil industry; as he goes into the oil business for himself; and as his strictly geological duties require greater imagination, more sound reasoning, and a broader basic understanding of the interrelation of the various sciences, so he comes to realize his own shortcomings and the need for better preparatory training for those now in the colleges. In effect, this means that the specialized field of petroleum geology is coming of age and is commencing to think about building its own standards of training and achievement.

Thus we see that geology and geologists are exercising a constantly expanding influence on the whole business of finding and producing oil and gas. There is no sign of a slowing down of this trend of usefulness, but, on the contrary, it is accelerating steadily, year by year. The petroleum geologist is becoming an "oil man" in every sense of the word, which, after all, is the best proof that he is keeping pace with the other applied sciences in the forward-moving front of scientific progress.

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[8] Report of Special Committee on College Curricula, F. H. Lahee, Chairman. Bull. Amer. Assoc. Petrol. Geol., vol. 25, pp. 969-972, May 1941. A later report of this committee may be found in vol. 26, pp. 942-946, May 1942.

METEORITES AND THEIR METALLIC CONSTITUENTS

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[With 6 plates]

HISTORICAL BACKGROUND

Meteorites are those portions of meteors which survive a passage through space and through our atmosphere and actually reach the surface of the earth. Of the countless number of meteors that enter the atmosphere only a very few of any size make a successful landing upon our earth. In this short review it will be shown that the air we breathe serves also as a shelter from meteoritic bombing.

Historically speaking, only comparatively recently has the mind of man accepted the fact that pieces of stone or metal could fall from the sky. This is all the more interesting when we observe how frequently references to the fall of a meteorite appear in old legends and records. In general the early descriptions are about as accurate as the ones reported to us today. An all-inclusive review of these old records will not be attempted, but a few will be cited to show not only their antiquity, but also the importance people have attached to these celestial objects. Man has been emotionally stimulated by seeing them fall and by reflecting on their origin, as well as being physically served by making practical use of them.

Many a meteorite has been reverently treasured by primitive peoples. We read of them being buried as sacred objects, worshiped as idols, even hammered into weapons and useful tools. Early explorers reported the use of objects made of iron by people who had no commerce with the outside world, as well as by people who were unfamiliar with methods of reducing iron from any of its ores. Many of these objects have been studied and found to be made of meteoritic iron.

Mythology has numerous old heroes who claimed to have had swords that had fallen from heaven. A dagger found at the site of Troy (Hissarlik) was reported by Dr. Schliemann to be a fragment of a

meteorite. The destruction of Sodom and Gomorrah may have been due to the impact of a falling meteorite; other explanations have been offered, but the meteoritic impact theory is as logical as any suggested. In Joshua X: 11 we read of great stones that fell from heaven on the Amorites in the battle at Gibeon. Again, in the 18th Psalm, we read: "The Lord also thundered in the heavens, and the Highest gave his voice; hail-stones and coals of fire."

In Acts XIX:24, there are accounts of "a certain man named Demetrius, a silversmith, which made silver shrines for Diana, brought no small gain unto the craftsmen." Farther along in the same chapter, 35th verse, "Ye men of Esphesus, what man is there that knoweth not how that the city of the Esphesians is a worshipper of the great goddess Diana, and of the image which fell down from Jupiter?"

When the Casas Grandes meteorite was found in Mexico, it was wrapped in mummy cloth, indicating probably that the people treated this object with the same respect that would be paid to one of their rulers. Prof. F. W. Putnam described some meteorites from southwestern Ohio that were found buried in an altar in association with the most precious objects of the mound builders.

At the time of Cortez'[1] conquest of Mexico, it was noted that only the most distinguished Aztecs had daggers and knives made of iron, a metal more highly prized than gold. The invading Spaniards reported no smelting furnaces for the reduction of iron, and when inquiry was made of a native as to the source of this iron, he would invariably point to the sky. Cortez and his followers certainly never guessed that the iron used by the Aztecs was of meteoritic origin.

The Descubridora meteorite from San Luis Potosi, Mexico, an iron mass of over 1,000 pounds, contained a copper chisel embedded in one of the fractures, indicating that Neolithic man was attempting to obtain and use this iron.

The famous "black stone" forming part of the wall of the Kaaba at Mecca, ancient religious center of the Arabs, is doubtless a meteorite. Only such an object, appearing miraculously from the sky, could have made such a profound impression as to become sacred.

Important events in the lives of the people are recorded on their coins. Many of the early Greek and Roman coins bear representations of meteorites. It has been reported that the metal from meteorites has even been used as a medium of exchange.

In 1812, when Napoleon was engaged in the battle of Borodino against the Russians, a stony meteorite was seen to fall not far from the Russian general. Napoleon won this battle, but lost the campaign against Russia. By a very narrow margin this meteorite missed being a celebrated historic specimen, for had the Russian

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[1] Hensoldt, H., Meteorites and what they teach us. Amer. Geologist (Minnesota), vol. 4, 1889.

armies rallied in this battle and defeated Napoleon, the meteorite would doubtless have been taken as a divine symbol that inspired them to victory.

Not only have meteorites stimulated man's imagination in the more or less remote past, but their scientific study has led to useful discoveries. According to the following quotation from a paper presented at the Second Empire Mining and Metallurgical Congress, Toronto, Canada, in 1927, by Robert C. Stanley, president of the International Nickel Company of Canada, the first use of iron and nickel alloys was suggested by a study of the Smithsonian collection of meteorites by Samuel J. Ritchie and John Gamgee:

> While Colonel Thompson was wrestling with the problem of the separation of the nickel and copper, which was subsequently solved by the Orford, and later by the Mond process, Mr. Ritchie had to face the problem of creating a market for his nickel. The World's annual consumption of nickel, in 1889, was four thousand tons, whereas the rich ores of his Canadian mines were ready to turn out twice that amount. The price, which had been $1 a pound or more when the Canadian deposits were first opened up only a few years before, had shrunk to 65¢ by 1889. The market was heavily over-stocked. German-silver, electroplating and coinage were practically the only uses for the metal. The future of the Canadian industry depended upon the extension of the market by finding new uses for nickel.
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> At this juncture Mr. Ritchie recalled an experience some years before in Washington. He had met there John Gamgee, an Englishman, who had interested the Government in the building of a refrigerated hospital ship for treatment of yellow-fever patients in the Gulf ports. Gamgee investigated ammonia refrigerating machines but soon found that cast iron would not hold compressed ammonia gas. He tried all kinds of alloys. Then, going one day through the Smithsonian Institution with Mr. Ritchie, he saw some nickel-iron meteorites and decided to try such an alloy. Mr. Wharton furnished some nickel with which Gamgee produced a very superior nickel-iron alloy which held the gas. Gamgee's ship was never built but he had demonstrated the possibilities of nickel-iron alloys.

NUMBER AND DISTRIBUTION OF METEORITES

The total number of known falls of meteorites for the entire world is about 1,400, which number includes only specimens now preserved in various collections. Not all of these have been studied, and as some of the discoveries lie comparatively close to each other, many of them may when studied be found to be individuals of the same fall. The United States alone has contributed more than 35 percent of the known falls or discoveries. This indicates a keen interest in the subject in this country, because the land area of the United States is a much smaller percentage of that of the entire world.

The distribution of meteorite localities is far from uniform over our 48 States. The fact that so many meteorites have been found in some States and so few in others may be due to several causes. There are areas where it is difficult to find a meteorite on the ground because

of the thick vegetation or the numerous rocks strewn over the surface. In other areas conditions are ideal for easy recognition of a meteorite on the ground. One reason why so many falls have been reported from certain districts is that the inhabitants have been encouraged to search for meteorites by being advised that these objects are easily salable. Once the residents of a district know what a meteorite looks like, and realize that there is a chance of monetary reward, it is likely that new finds will be made.

There have been so many meteorites reported from certain districts that it has become necessary to exercise caution before announcing a discovery as a new one. It is increasingly important that the exact locality of the place of discovery be recorded; the old practice of stating general localities such as counties no longer suffices to establish new falls.

It is not only necessary to have a portion of any newly discovered specimen examined in the laboratory, but it is also important to have it examined where complete records of all falls are available, and preferably where there is a large collection of meteoritic material available for comparative study. Sections should be cut from the mass to be compared with the other meteorites previously reported from that area. Many meteorites are so similar in structure and composition that even after these precautions are taken, it is difficult to state definitely whether a particular specimen is a new discovery or is merely a part of a fall previously recorded from that area.

The United States National Museum has specimens of over 75 percent of all the reported meteorites from this country and nearly 55 percent of the total reported for the entire world. Thus excellent reference material is available for the investigation of a newly discovered fall. Individually all the specimens are not of equal importance, but collectively they are most important for the study of variations in the structure and composition of the different groups. Some of the specimens weigh more than a ton, others but a few grams. It is necessary, however, to have sizable samples in studying objects as complex and varied as meteorites.

FLIGHT OF A METEORITE

At the time a meteor enters the outer atmosphere perhaps 40 miles or more above the earth, its speed is known to be very great. The slowing down of the rapidly moving object causes the mechanical energy to be converted into heat with the result that the air compressed in front of it becomes very hot. As the density of the air increases, the velocity of the meteor is more retarded, and at the same time the amount of heat thus generated rapidly increases. When the falling body is within 6 to 9 miles of the earth's surface, its velocity usually is so reduced that the generation of heat practically

ceases and it therefore is no longer luminous. During the fall heat diffuses slowly into the mass, so that the outside rapidly increases in temperature. Soon the surface is softened and removed by the scouring action of the air. This type of erosion progresses with the penetration of heat. As the falling mass is constantly entering a denser atmosphere, the frictional resistance increases; consequently, the stripping away of the outside goes on at an accelerated rate. The size of the falling body is reduced rapidly.

It has been demonstrated that the symmetrical etch pattern of a cross section of an iron meteorite is easily and rather completely disrupted by heating to a bright red heat. So if heat has penetrated deeply into these irons their interiors would be found without this formal structure. Examinations of scores of cross sections of irons have been made, and no evidence exists to show that the interior was heated during the flight. The heated zone detected by study of sections is seldom more than 1 or 2 cm. thick.

The surfaces of many stony meteorites show well-defined markings that indicate the orientation of the body through a portion of its flight. Since only a few iron meteorites have been seen to fall, most of those now known are old ones on which the flight markings have been removed by alteration. The finding of such a perfectly preserved set of flight markings as the Freda, N. Dak., iron is unusual.

The outer surface of this specimen tells the story of its struggle through our atmosphere. The Freda iron is small, weighing only 268 grams, but its shape and internal structure make it of great interest, and its flight markings are beautifully preserved. The nose of this specimen is turned over just as though it had been hammered. There is no reason to suppose that this resulted from its impact with the ground since it was found in soft sod; hence it appears that this rolled edge is due to the resistance offered by our atmosphere. The turned-over nose must have developed during the last portion of the iron's flight, because had it developed very high above the earth, it would have been stripped off before the meteorite landed. This mass must have attained a very high velocity to produce air pressure capable of turning or battering the metal in such a fashion. A determination of the composition of this meteorite showed that it contained 23.49 percent nickel and 75.86 percent iron. Material of such a composition would not change from the solid to the liquid phase until it reached a temperature of about 1470° C. It would not be necessary, however, to attain that temperature to soften the metal to a point where it could rather easily be washed off by the air stream. The temperature required to accomplish this would probably be several hundred degrees lower than the melting point.

In addition to the more delicate lines on the surface of meteorites, a number of depressions are usually present; some are shallow and

wide, others narrow and deep, and examples are known in which a hole pierces the entire mass. It is sometimes possible to determine the direction of the air flow by rubbing one's hand over the surface of the meteorite. The surface feels smoothest when the motion of the hand is in the same direction as the air flow, a decided difference being sometimes felt on rubbing the surface in the opposite direction.

When the Reed City iron was sectioned in our laboratories, a number of slices exhibited areas on the edge where heat had locally disrupted the internal structural pattern. A thin film of black solidified liquid oxide lies between the granular area and the normal octahedrite structure. This oxide film (pl. 4) must mean that there was a small invasion of melted oxide and iron, the latter developing a granular structure in cooling. If the mass had remained in a fixed position a little longer, perhaps this granular portion would have been swept out, deepening the depression and also making possible the formation of whirlpools of air which would further abrade the meteorite, forming the pits common on so many irons. Unfortunately these structural features were not observed until the individual specimen had been cut into sections so it is impossible to relate this structure to any flight markings that may have been on the surface of the specimen.

The air does an effective piece of work in rubbing out these celestial bombs. Their size when they first enter our atmosphere is not known with any accuracy, but there is reason to believe they are sometimes very large. Records of different falls show that very few large ones get through to the earth, and we should indeed be thankful that the air is such an effective screen against meteoritic bombs. The total weight of material in any shower may be large but it is unusual to find individual specimens weighing as much as 500 pounds. Good observations on the Chicora, Pa., fall indicate that a large mass did survive the passage through the atmosphere until it reached a level of about 12 miles above the earth. At this point something happened —probably the mass was crushed by the pressure of the resisting air. Calculations based upon direct observations indicate that at the 12-mile level the mass must have weighed in the neighborhood of 500 tons. Only 303 grams of this meteorite are known to have reached the earth, which is indeed a very small fraction of what existed 12 miles up.

In a few widely scattered localities on this earth, large holes bear witness to the crash of super-meteorites. All but one of these occurred before the dawn of recorded history; consequently we know nothing regarding the frequency of such events. One of these super-meteorites that did fall in our time—the Tunguska meteorite which crashed down on Siberia on June 30, 1908—really gave our world a good rap. European seismographs recorded a strong ground wave, and baro-

graphic instruments in England recorded pressure waves. An engineer on the Trans-Siberian railway had to stop his train the night of the fall to prevent its being derailed by earth waves—and this was more than 400 miles from the place where the meteorite hit. Fortunately the region of the fall was very sparsely inhabited, and for that reason it was a long time before the world knew what happened that night. When the scene was reached by outsiders, it was found that all the trees within a radius of 60 miles of the center of impact were blown flat. They were not strewn over the ground in a confused manner, but were arranged radially from the center of impact. For much of the distance that the trees were blown over, the wood was charred by the heat waves. It is doubtful whether any man or animal could have survived within many miles of the spot where the mass hit. It would be difficult to pick a spot on the globe where such an event would involve less danger to man. However, it would have been a different story had this meteorite arrived on earth 4 hours and 47 minutes later, because it would then have made a perfect hit on a large city—Leningrad.

Canyon Diablo crater in Arizona is the largest of these meteoritic holes, and from the area surrounding its rim several tons of iron meteorites have been collected. None of the individual specimens thus far located is very large, the maximum weight being about 1,000 pounds, but some of these large specimens have been found several miles from the crater rim. No meteoritic material has as yet been found around the Siberian fall, but collecting in that area is most difficult. The quantity of meteoritic material buried at either place is problematical, and also the size and weight of the mass that struck the earth. It is certain, however, that a most violent explosion resulted when such a vast quantity of energy was abruptly checked and turned into heat and wave energy.

TYPES OF IRON METEORITES

A few years ago the National Museum received several irons from northern portions of Chile where towns and named geographic landmarks are not abundant. The reported localities were given in miles from railroad stations or mining camps. When these irons were sectioned all were found to have similar structures belonging to the hexahedrite group. It was then hoped that chemical investigations would establish certain differences, but as the work progressed and the results were tabulated, it was found that they were all practically identical. The distribution of these nine Chilean meteorites is confined to a narrow strip extending 8°51′ of latitude north and south and 1°56′ of longitude east and west. It is hardly logical to consider all of them as being a part of the same fall, and yet it is equally difficult

to believe that nine different meteorites of identical type would strike the earth within such a limited area.

It is well known that there is a definite relationship between the structure and the composition of iron meteorites. Since the analytical work on irons is not as simple as many chemists once believed, few of the old analyses can be used in interpreting this relationship. Hence it is very likely that the variation in nickel now reported in the literature may in large part be due to faulty methods or to improper sampling.

Search of the literature revealed a number of analyses which agree perfectly with the results on the Chilean material. The finding of so many identical analyses from all parts of the world suggests either that (1) all meteorites of similar composition and structure have a common origin and their distribution over the earth is due to their having fallen at different times, or (2) meteorites should be considered as forming from melts of iron and nickel, etc., and the resulting structure of the alloy will depend upon the composition of the original melt as well as on the speed with which it cooled. Evidence definitely indicates that the second supposition is the more logical one and that the differences in meteorites are due not only to differences in the composition of the original melt, but also to temperatures and rates of cooling.

In other words, whenever the proportion of nickel and cobalt in metallic meteorites is less than about 6 percent, only structures of one class—hexahedrites—will form. When the nickel and cobalt content in the original melt is higher than 6 percent, a second alloy will begin to appear. When the large areas of simple structure are broken up by inclusions of this second alloy arranged in a definite pattern, we have a structure known as an octahedrite. The rate of cooling determines the ease with which the different components migrate and increase in size. When the percentage of nickel and cobalt is only slightly higher than 6 percent, only a little of the second alloy, known as taenite, will form, so that there are rather wide bands of one alloy (kamacite) separated by specks or thin films of taenite. This combination produces what we call coarse octahedrites. As the nickel content increases, finer and more delicate structures appear. It is not easy to say whether composition or rate of cooling is the more important factor in the production of a certain structure.

The three classes of iron meteorites are hexahedrites, octahedrites, and ataxites, each having distinctive general features that are most noticeable after a polished surface is etched. Certain chemical differences also exist, but there is no sharp boundary between the different groups and they intergrade with one another.

Hexahedrites.—Analyses of different meteorites of the hexahedrite type show there is little variation between any two of them (table 1). Hence the chemical evidence indicates that a rather definite alloy is formed which produces rather simple etch patterns consisting of one or more sets of parallel lines. The name kamacite is given to this composition and pattern, and the delicate structural lines are called Neumann lines. A meteorite containing only this relationship of iron and nickel is called a hexahedrite.

The compositions of hexahedrites are not absolutely definite. The variations from the average can be seen by comparing the individual index ratios, obtained by dividing the molecular ratio for iron by the sum of the molecular ratios of nickel and cobalt. The average index ratio of analyses given in columns 1 to 15 of table 1 is 16.7, and the average ratio for 6 north Chilean hexahedrites given in column 17 is 16.9. Bearing in mind that all these meteorites probably did not form under identical conditions, we see that the amount of variation is relatively small.

Table 1.—*Composition of hexahedrites*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Fe	93.26	94.14	93.75	93.30	93.93	94.02	93.39	94.03	93.39	93.47	93.59	93.82	93.06	93.75	93.30	94.05	93.58
Ni	5.73	5.30	5.51	5.79	5.52	5.48	5.62	5.33	5.60	5.55	5.68	5.21	5.33	5.43	5.39	5.46	5.60
Co	.75	.63	.51	.29	.61	.22	.68	.95	.78	.52	.66	.92	1.00	.68	.78	------	.29
S	------	.19	------	.18	------	.04	------	.07	T	None	.08	.08	.08	.08	T	------	T
P	.25	.28	.20	.20	.34	.30	.31	.23	.22	.27	.25	.34	.31	.19	.32	------	.25
C	.03	------	.08	------	.04	------	------	------	.12	.03	------	.09	------	------	------	------	------
Cr	------	.05	------	.04	------	.02	------	.02	------	------	.02	.05	.23	------	------	------	.02
Cu	------	.06	------	T	.02	------	------	.04	T	T	.01	.07	------	------	------	------	------
Ins	------	------	------	.08	------	------	------	.01	------	------	------	------	.08	------	.07	------	.01
Cl	------	------	------	------	.06	------	------	------	------	------	------	------	------	------	------	------	------
Mol. ratio $\frac{Fe}{Co+Ni}$	15.1	16.8	16.2	16.2	16.1	17.5	16.0	15.8	15.4	16.0	15.6	16.2	15.5	16.6	15.4	------	16.9

T=trace.

Column 1. Uwet, Africa. Min. Mag., vol. 17, p. 127, 1914.
2. Walker County, Alabama. Meteoritenkunde, vol. 3, p. 173, 1905.
3. Iredell, Texas. Amer. Journ. Sci., ser. 4, vol. 8, p. 415, 1899.
4. Bruno, Sask., Canada. Amer. Journ. Sci., ser. 5, vol. 31, p. 300, 1936.
5. Murphy, North Carolina. Meteoritenkunde, vol. 3, p. 227, 1905.
6. Cedartown, Georgia. To be described by S. H. Perry.
7. Summit, Alabama. Amer. Journ. Sci., ser. 3, vol. 40, p. 322, 1890.
8. Scottsville, Kentucky. Meteoritenkunde, vol. 3, p. 218, 1905.
9. Warialda, Australia. Rec. Geol. Surv., New South Wales, vol. 10, p. 75, 1921.
10. Barraba, Australia. Rec. Geol. Surv., New South Wales, vol. 10, p. 75, 1921.
11. Hex River, Africa. Meteoritenkunde, vol. 3, p. 223, 1905.
12. Braunau, Bohemia. Meteoritenkunde, vol. 3, p. 207, 1905.
13. Holland's Store, Georgia. Meteoritenkunde, vol. 3, p. 240, 1905.
14. Cerros del Buei Muerto, Chile. Chemie der Erde, vol. 7, No. 3, p. 499, 1932.
15. Coahuila, Mexico. Amer. Journ. Sci., vol. 239, pp. 407–411, 1941.
16. Boguslavka, Siberia, U. S. S. R. Amer. Mineral., vol. 26, pp. 546–550, 1941.
17. Average of 6 Chilean hexahedrites. Amer. Mineral., vol. 26, pp. 546–550, 1941.

Octahedrites.—More abundant in nature than hexahedrites and with a wide range of structural and chemical composition are the iron meteorites known as octahedrites. If etched sections of this group are carefully observed there will be noticed areas which have etching lines similar to those displayed in the hexahedrite group.

It will be further noted that these areas form rather long but narrow bands and are separated from each other by delicate lines of an alloy with a totally different appearance. Kamacite is the name given to the metal in these wide lath-shaped areas and the metal in the delicate lines bordering the kamacite is taenite. The chemical analysis (table 2) shows that this group of meteorites always has a higher percentage of nickel than hexahedrites. At this point the explanation of structures begins to become apparent. The single alloy, kamacite, of which hexahedrites are made up, is composed of iron that is about saturated with respect to cobalt and nickel. Any excess of these metals over that needed to make kamacite combines with iron to make a second alloy, taenite, and the distribution arrangement of these two alloys forms an octahedral pattern. Taenite is slightly different in its acid-resisting properties, and on the etched face of a meteorite it stands out in relief against the kamacite.

When a series of etched faces of octahedrites is spread before the observer, a difference in width is noted between these kamacite bands in different specimens. Some are very narrow and surrounded with a continuous thin, but well-developed, line of taenite; others have a very wide, sometimes irregular-shaped, area of kamacite with only a mere suggestion of taenite around it. In fact these octahedrite and hexahedrite groups reach a point where there is little difference between them.

The relationship between composition and structure is rather simple to this point, but as structures of more and more octahedrites are examined it is noticeable that increasing narrowness or fineness of the kamacite bands does not always guarantee progressively higher nickel content. It is true that medium or narrow widths of the kamacite bands will always imply definitely higher nickel content than is found in the very coarse octahedrite structures, but occasionally it is impossible to predict definitely which of two rather similar octahedrite structures will have the higher percentage of nickel. Consequently there is good reason to believe that another factor should be considered besides the rate at which a melt cools down, and that is the length of time it was held at a fixed temperature, because this may have something to do with the fineness or coarseness of octahedrite structures. In the laboratory it is difficult to retain for a long time a prepared nickel-iron mix at a temperature where the metal is a solid but still at a temperature sufficiently high for the molecules of these two alloys, kamacite and taenite, to migrate and segregate from each other.

Quick freezing can create a structure of thin areas of kamacite separated by taenite. When the meteorite freezes before the taenite can collect together—or, to express it differently, before the kamacite

can expel the taenite—thin lath areas of kamacite should be produced. Such a pattern is known as a fine octahedrite. The rate of cooling is important and may be responsible for many structures in iron meteorites.

TABLE 2.—*Composition of octahedrites*

(E. P. HENDERSON, *analyst*)

	1 Mt. Joy	2 Sandia Mts.	3 El Burro	4 Sardis	5 Nelson County	6 Grant	7 Grand Rapids	8 Glorieta
Fe	92.98	92.46	93.10	92.09	91.90	88.63	89.80	87.08
Ni	5.79	5.92	6.03	6.60	6.78	9.32	9.38	11.79
Co	.61	.53	.34	.47	.34	.63	.53	.42
P	.20	.68	.32	.24	.21	.57	.14	.37
S		Trace	Trace	None		.03		
Insol.	.01	.07	.01		.07		.03	.01
Mol. ratio $\frac{Fe}{Co+Ni}$	15.4	15.1	15.5	13.3	12.7	9.4	9.5	7.8

NOTE.—Nos. 1-5 are coarse octahedrites, Nos. 6-8 are medium to fine octahedrites.

Although it is impossible to define exactly the boundary between hexahedrites and octahedrites, it is obvious that the two tables indicate the approximate position of this boundary. The accuracy with which nickel and especially cobalt can be determined is limited by certain sources of error; hence it is increasingly difficult to fix boundaries for the chemical composition of either of these groups. The behavior of cobalt and nickel is practically identical in these alloys, and in discussing the compositions of these groups, therefore, the cobalt and nickel together are considered as a unit.

There are octahedrites that have large areas of kamacite separated from adjoining areas of the same alloy by only a fine line. Careful search along these boundaries usually will detect some taenite; but as the compositions approach the limits of solubility for cobalt and nickel in iron at the different temperatures, a time comes when there will be formed only a trace of taenite, which can be very easily overlooked. Thin, discontinuous plates of taenite were found in the El Burro specimen, and none at all in the Mount Joy and Sandia Mountains specimen. Hence the composition of these three meteorites is near the border line between the octahedrite and hexahedrite groups.

A simplified equilibrium diagram of the iron-nickel system given by E. A. Owen and A. H. Sully[2] traces the composition and temperature range for the boundary of kamacite (hexahedrite) and kamacite-taenite (octahedrite) structures. It shows (fig. 1) that at 400° C. kamacite contains its maximum nickel content, or slightly over 6 percent; at 300° C. the solubility had decreased to 5 percent nickel.

[2] Phil. Mag. and Journ. Sci., vol. 27, No. 184, p. 614, 1939.

In figure 1, the location of the line AB, separating the α phase, kamacite, and the $\alpha+\gamma$ phase, kamacite and taenite, rather clearly defines the chemical compositions for the two groups given in tables 1 and 2. Since the conditions of heating and rate of cooling of meteorites are not understood, they cannot be used to modify the nickel-iron diagram prepared under a controlled environment. However, their compositions and structures should be consistent with the compositions of their respective fields on the phase diagram.

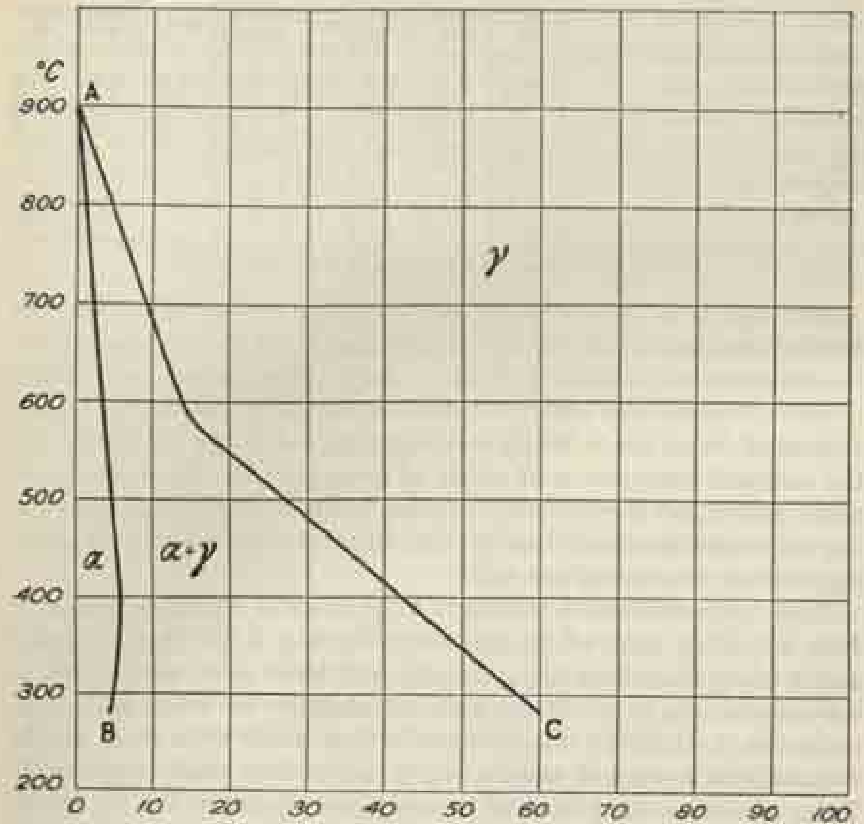

FIGURE 1.—Equilibrium diagram of iron-nickel system below 1000° C. Composition expressed on horizontal line is the percentage of nickel in iron.

Ataxites.—Ataxites lack the precise structural patterns of either hexahedrites or octahedrites. Perhaps some day this group, which varies widely in its nickel content, will be simplified; however, at the present time into this class fall all the irons that cannot readily be classified as belonging to either of the other classes. It is significant that the cobalt-nickel content for some ataxites closely parallels that of hexahedrites. In certain other ataxites there is a vestige of octahedrite pattern and also a chemical composition that lies within the range for octahedrites. In addition to the above there are several

nickel-rich ataxites in which the nickel content is much higher than that of any octahedrite (see tables 2 and 3).

The same general compounds of iron, nickel, etc., that occur in the other groups are present in ataxites. The taenite is more abundant in ataxites, and there is reason to believe that the nickel content of the taenite is higher than in that found in octahedrites. Following the line AC on figure 1 from higher temperatures to lower, we note that as the melt cools the position of the line is shifted toward an increasing nickel content. Investigation may show that taenite in the same meteorite varies in composition.

Studies of ataxites have not as yet progressed to the point where all the structures can be accounted for. The logical approach to an understanding of ataxites is through more complete investigation of the features of both hexahedrites and octahedrites.

Only those ataxites rich in nickel were included in table 3. Nickel-poor varieties, with a composition similar to that of hexahedrites or coarse octahedrites, exist, but the majority of published analyses of ataxites indicate that their cobalt and nickel content falls within the higher limits of composition of the finest octahedrites and extends even beyond this range.

TABLE 3.—*Composition of high-nickel ataxites*

	Meteorite (name of analyst in parentheses)								
	Monahans (Hawley)	Nordheim (Gonyer)	Piñon (Hawley)	Tlacotepec (Hawley)	Tawallah	Iquique (Henderson)	Hoba West (Hey)	Hoba West (Gordon)	Freda (Henderson)
Fe	88.30	87.70	82.52	82.44	82.29	83.47	83.44	82.40	75.88
Ni	10.88	11.69	16.32	16.23	16.90	15.99	16.24	16.78	23.49
Co	.68	.51	.67	.66	1.09	.32	.76	.74	.66
Cu	.09	Trace	.03	.09			.03		N.D.
Cr	.022		.019	.03					N.D.
P	.09	.04	.40	.06	None	.09	Trace		.15
S	.04	Trace	.10	.07	None		Trace	.02	
Mol. ratio $\frac{Fe}{Co+Ni}$	7.9	7.6	5.17	5.2	4.8	5.3	5.1	4.9	3.4

Because most of the analyses on nickel-rich ataxites are very old and the cobalt and nickel contents may not be very accurately determined, a more complete table of this class was not attempted. Three of the eight meteorites listed in this group, namely, Nordheim, Tawallah, and Freda, have a slightly developed octahedral structure. In both the Tawallah and Freda descriptions, mention is made of a fine-grained acicular ground mass through which occur inclusions of kamacite. In each case kamacite is surrounded by areas which are largely taenite and which appear bright in the published photomicrographs because taenite is resistant to the etching reagents used. This arrangement is explained by assuming that the kamacite separated

out from the ground mass surrounding the area, leaving the taenite segregated; hence, localized areas of kamacite and taenite occur.

STONY METEORITES

The metallic inclusions in stony meteorites will be only briefly discussed. The principal point to be brought out is the similarity in range of chemical composition of the iron in stony meteorites and in iron meteorites. The composition of the metal in stony meteorites of the chondritic group seems to change as the proportion of the metal to the silicates varies. When there is an abundance of metal, its cobalt-nickel content is usually relatively small; likewise when only a few metallic inclusions occur they are usually very rich in cobalt and nickel.

TABLE 4.—*Comparison of the molecular ratio index* $\frac{Fe}{Co+Ni}$ *of iron in meteorites*

Iron meteorites				Stony meteorites		
Hexahedrites and octahedrites		Ataxites				Percentage of metal in stony meteorites
	Ratio		*Ratio*		*Ratio*	
Hexahedrite group (Average)	16.3					
El Burro	15.5					
Mt. Joy	15.4					
Sandia Mountains	15.1					
Oasno	14.9					
				Kimble	15.1	11.3
				Benoubbin	14.5	69.9
				Suwahib	13.0	15.1
Nelson County	13.7					
Ballinger	13.6					
Sardis	13.5					
Santa Rosa	12.9					
				Cuero	11.5	22.7
				Hedjaz	11.5	11.1
				Ekeby	[1] 10.3	18.6
Grand Rapids	9.5					
Grant	9.4					
		Guffey	8.4	Plantersville	8.9	19.
		Monahans	7.9	Morven	8.7	13.2
		Nordheim	7.6			
				Perpeti	6.2	8.24
				Lundsgard	[1] 6.2	7
				Tenham	5.6	7.1
		Iquique	5.3			
				Launton	5.2	8.4
		Pinon	5.17			
		Hoba West	5.1			
		Tawallah	4.8			
		Freda	3.4			
				Ensisheim	3.4	3.2
				Soko Banja	2.9	4.2
				Chicora	2.06	2.8

[1] The analyst failed to determine the percentage of Co.

Several authors have called attention to this fact and other tables have been published.[3] An independent check was made of this point by selecting at random a limited number of well-studied chondritic meteorites and arranging them in a series starting with the specimen having the highest index ratio to determine whether some correlation

[3] Prior, G. T., Min. Mag., vol. 18, p. 28, 1916.

would be found. It so happened that the highest index ratio in the group selected corresponded to the index value of the octahedrite group.

The manner in which the iron occurs in these stony meteorites must be carried in mind by the reader in order to appreciate the problem presented. The iron is generally localized into small, irregular-

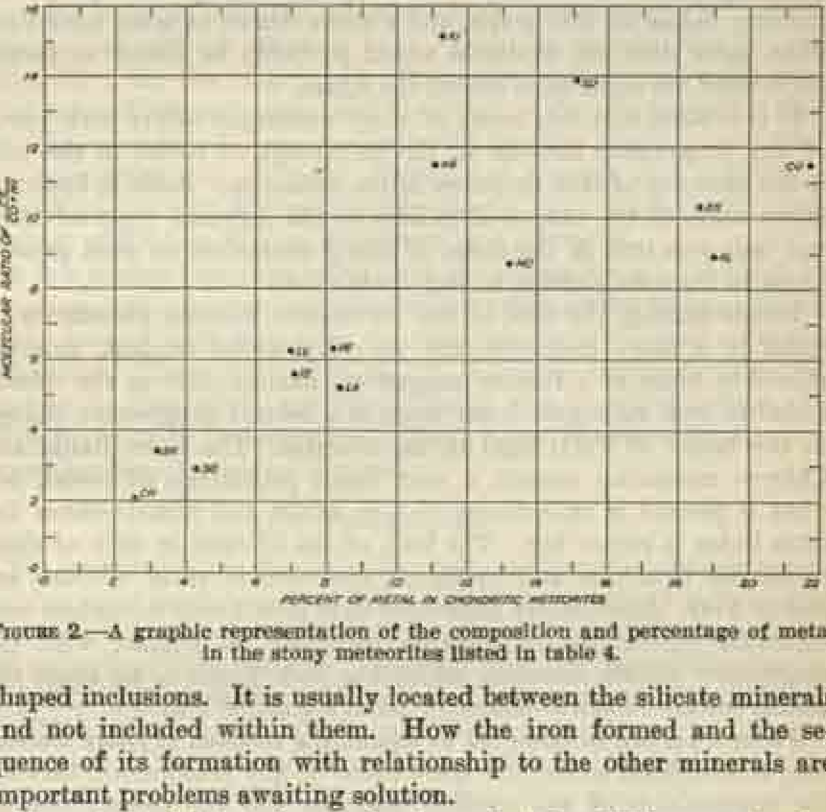

FIGURE 2.—A graphic representation of the composition and percentage of metal in the stony meteorites listed in table 4.

shaped inclusions. It is usually located between the silicate minerals and not included within them. How the iron formed and the sequence of its formation with relationship to the other minerals are important problems awaiting solution.

The cobalt-nickel to iron ratio shows that in solid iron meteorites a rather continuous series exists. This index ratio ranges from 16.+ in the case of hexahedrites down to 3.+ in the ataxites, and there is little question but that the ataxite ratios could be extended even lower.

The last column in table 4 gives the percentage of metal present in the specimens, and an examination of the last two columns indicates that some sort of correlation does exist. Just why there should be any relationship between the composition of the iron and its abundance in a meteorite of this type is very difficult to explain.

The true relationship between the last two columns in table 4 is best seen when these values are plotted. In figure 2 the vertical component corresponds to the index ratio and the horizontal com-

ponent to the percentage of iron in the meteorite. The points on the graph represent the specific meteorites listed in table 4. There is a grouping of points in the lower left-hand portion of the graph. Points Ch,[4] So, and En are rather well grouped, as are also points La, Te, Lu, and Pe; the other seven are so widely dispersed that it is useless to attempt a serious discussion of a curve based on these data. A straight-line relationship would not necessarily be expected in plotting values on this graph, and a curve drawn at some later time when more data are available would probably be found to flatten out toward the right-hand side of the figure.

It is evident that this series of stony meteorites offers little proof of any progressive increase in the percentage of nickel in the iron as the quantity of iron decreases in the meteorite. Table 4, however, shows some of the ranges of indices of the different types of irons and indicates that in the metal of stony meteorites an even greater range in the cobalt-nickel to iron ratio exists.

Before leaving the idea of the correlation between abundance of metal in a stony meteorite and its cobalt-nickel content, mention should be made of a further suggestion, namely, that as the cobalt-nickel to iron ratio gets lower there is a related progressive change in the ratios of FeO:MgO in the silicates. The Soko Banja and Chicora meteorites contain a very small percentage of metal, but what is present is exceedingly rich in cobalt and nickel—hence the ratio index is rather low. The bulk of the silicates in each of these meteorites is olivine and pyroxene, and both of these silicates are rich in FeO. Again many meteorites have been found to contain considerable percentages of metallic inclusions in contact with the magnesium silicate enstatite, which has been found to be about the purest enstatite known—almost without a trace of iron.

From what can be observed by examining sections of stony meteorites, it is difficult to see how there could be any relationship between the composition of the metallic portions and the composition of the silicate minerals. Judging from the physical relationship of the iron to the other minerals present, it would appear that the metal solidified later than the silicate minerals. A chondrule is shown in plate 6 completely surrounded by a ring of metal, and such features as these are not uncommon. Merrill[5] called attention to the thread-like forms of iron penetrating silicates, and it is difficult to see how these delicate threads could enter a silicate mineral unless the iron solidified in the fractures of previously formed minerals.

A convincing array of evidence can be offered to show that chondritic meteorites are tuffs—that is, they represent a type of rock

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[4] The first two letters of the meteorite names are used to designate the position on the graph.

[5] Proc. U. S. Nat. Mus., vol. 73, art. 21, 1928.

mechanically brought together; hence, the various components of such stones are associated purely by chance. Thin sections of chondritic meteorites show some complete chondrules, but usually there are a great number of fragments of chondrules present. The fragmental nature of this class of meteorites is a conspicuous feature. Foshag[8] stated: "The agglomeratic nature of chondritic meteorites leaves little doubt that they are volcanic tuffs." Since in many stones the iron occurs enclosing chondrules or penetrating the minute fractures of silicate minerals it is logical to assume that it was deposited after the fragmental silicate material was partially consolidated. With such good and abundant evidence suggesting that the silicate materials were mechanically brought together, and that iron was introduced after the silicates had formed, it is impossible to understand why any relationship should exist between the composition of the iron and its abundance in a meteorite.

A few studies have been made upon the etch patterns of the iron in stony meteorites, and these studies indicate that all the features found in the iron of iron meteorites are also present in the iron of stony meteorites. There is no question but that some of the metallic inclusions in these stones are exceptionally rich in nickel—above the range found in the iron meteorites—hence it is to be expected that a few unusual etch patterns may be found.

CONCLUSION

The purpose of this discussion has been to show that some progress is being made in relating the various phenomena observed in the study of meteorites, although some of the most conspicuous features are still but imperfectly understood. The description of stony meteorites is very difficult, and often a published account is so general that it is impossible properly to classify the specimen or to correlate it with other meteorites. The study of meteorites is only just beginning, and the system of classification is still in the formative stage. It is unfortunate that the interest of many persons in these objects is merely that of the collector in possessing something extremely rare, when so many interesting problems await the attention of ambitious students.

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[8] Amer. Mineral., vol. 26, p. 137, 1941.

[illegible]

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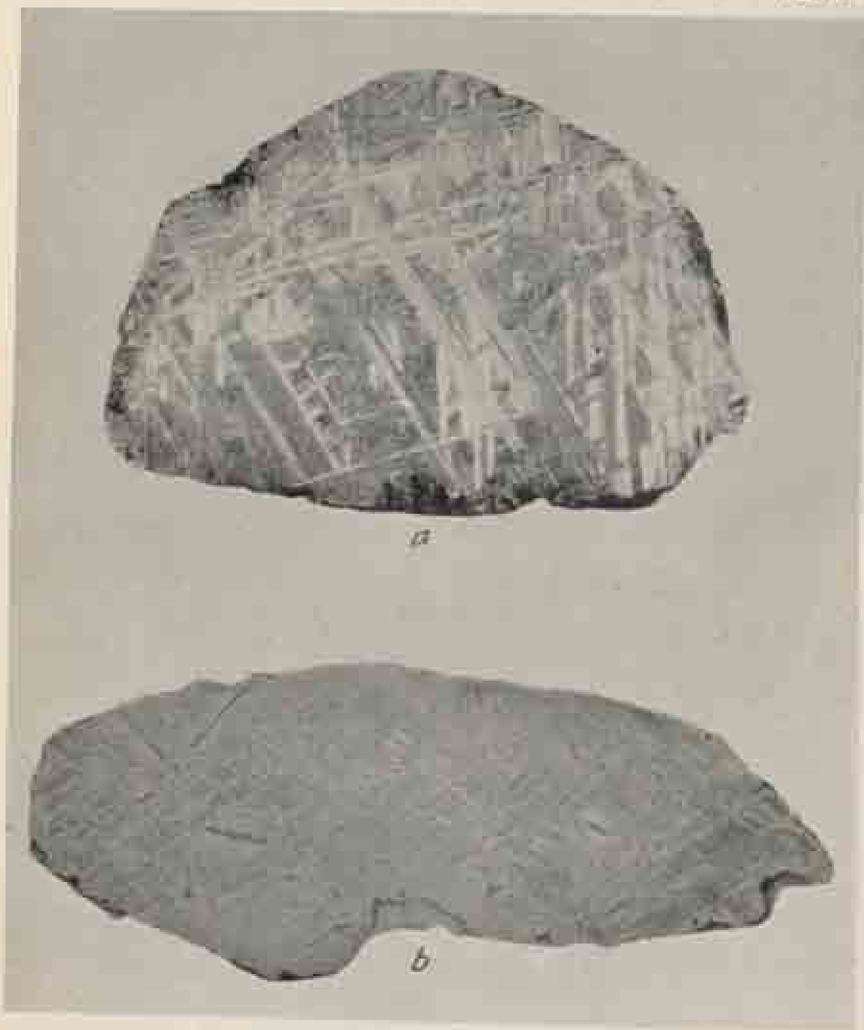
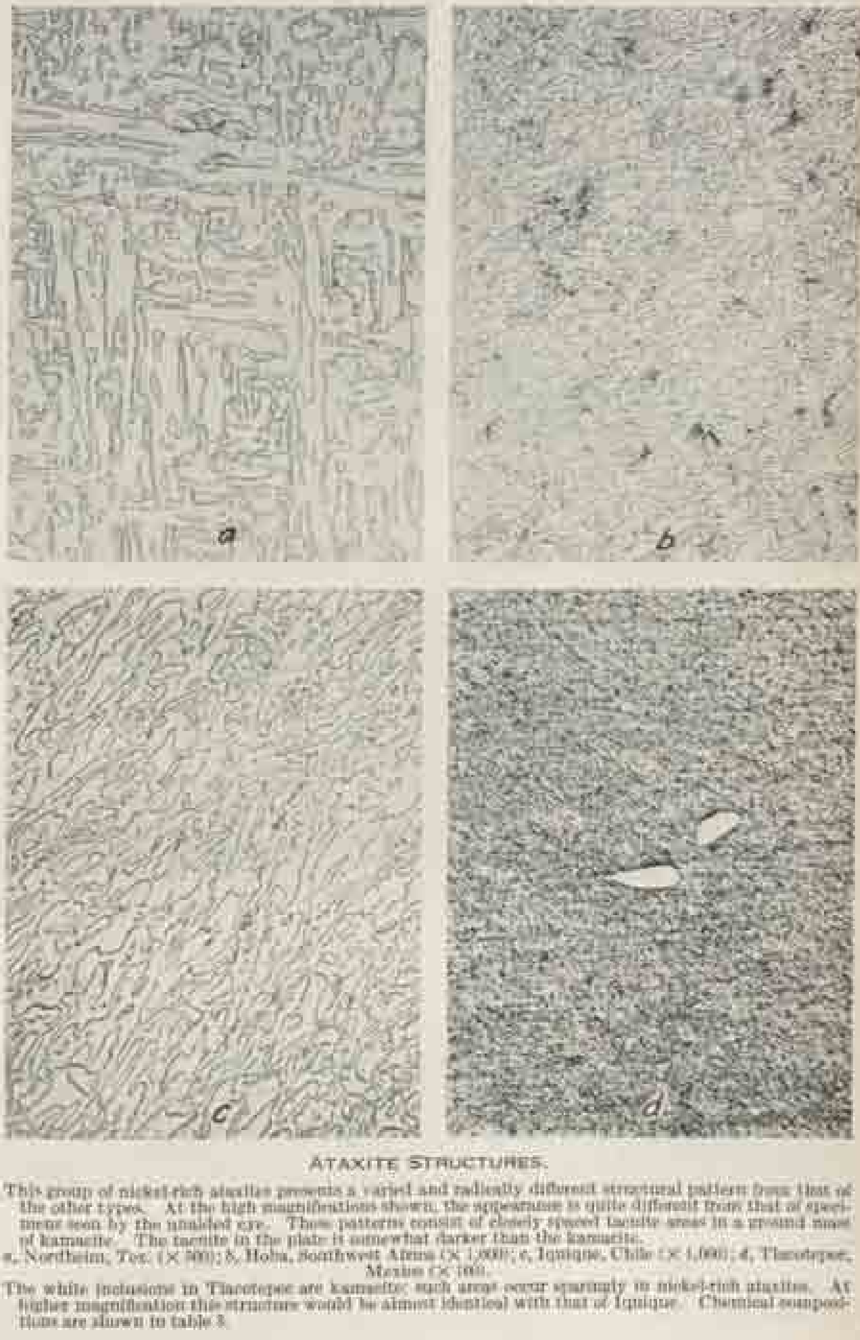
FLIGHT MARKINGS.

The flight markings on the surface indicate that the meteorite held a fixed position through a portion of its fall. They also show how the size of a meteorite is reduced by air friction.
a and b, two views of the surface of an iron meteorite, Freda, N. Dak.; c, the surface of a stony meteorite Tulia, Tex.



FINER OCTAHEDRITE STRUCTURES.

Narrow bands of kamacite separated from each other by thin lines of taenite. Structures such as these indicate nickel content higher than that of the coarse octahedrite.
a, Grand Rapids, Mich. (for composition see table 2); b, Reed City, Mich. Centered at the bottom is an area where the orderly octahedrite structure has been broken up. This is assumed to be the result of localized heating during its flight. The rodlike inclusions of troilite at the upper left cut through the octahedral structure.

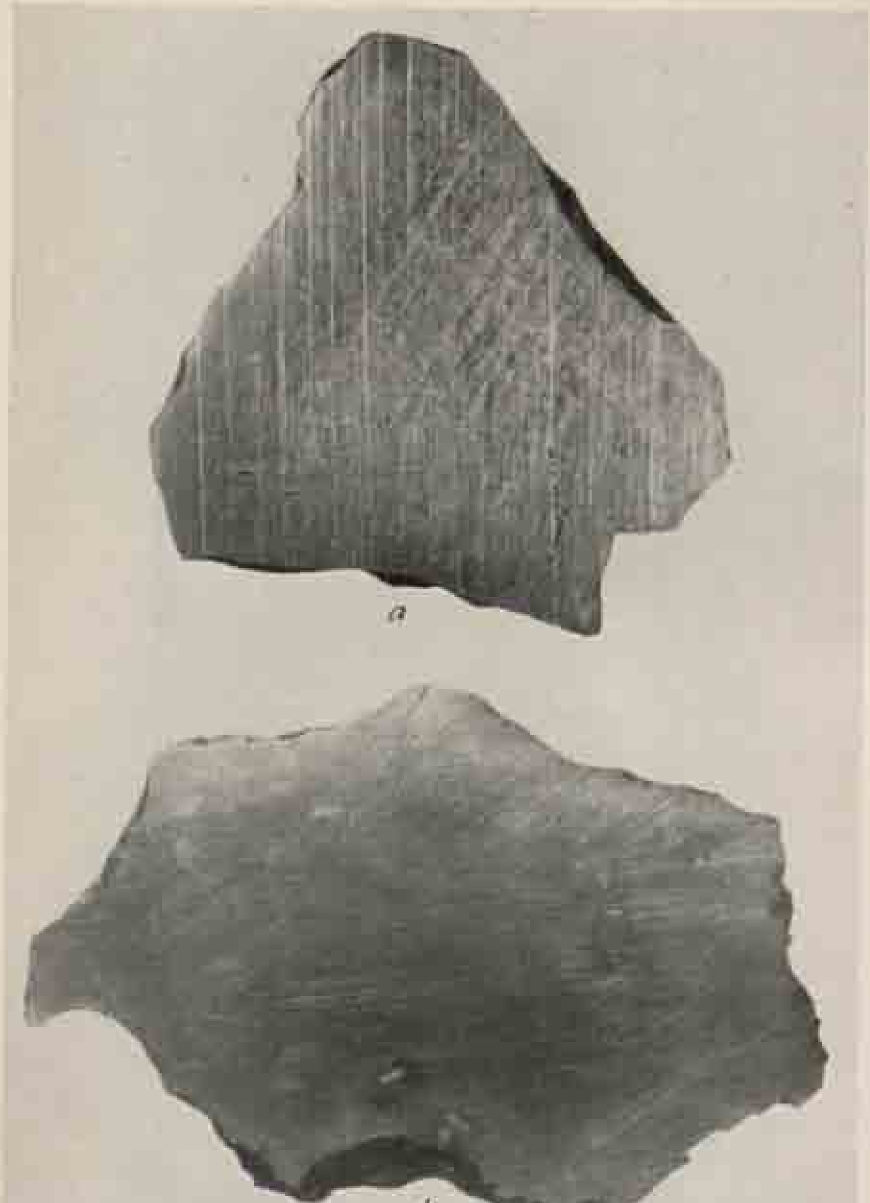


ATAXITE STRUCTURES.

This group of nickel-rich ataxites presents a varied and radically different structural pattern from that of the other types. At the high magnifications shown, the appearance is quite different from that of specimens seen by the unaided eye. These patterns consist of closely spaced taenite areas in a ground mass of kamacite. The taenite in the plate is somewhat darker than the kamacite.

a, Nordheim, Tex. (× 500); b, Hoba, Southwest Africa (× 1,000); c, Iquique, Chile (× 1,000); d, Tlacotepec, Mexico (× 100).

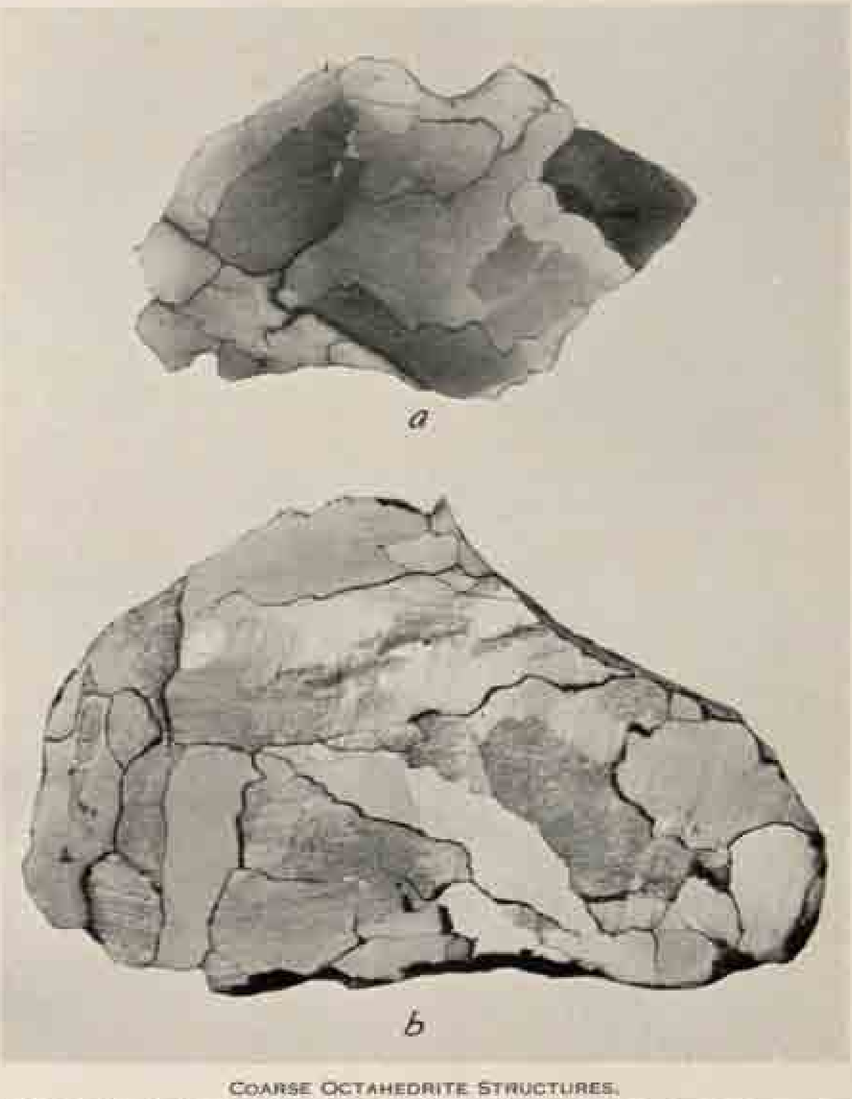
The white inclusions in Tlacotepec are kamacite; such areas occur sparingly in nickel-rich ataxites. At higher magnification this structure would be almost identical with that of Iquique. Chemical compositions are shown in table 3.



HEXAHEDRITE STRUCTURES.

Meteorites of this class are made up of a single alloy, kamacite; the parallel rulings are known as Neumann lines.

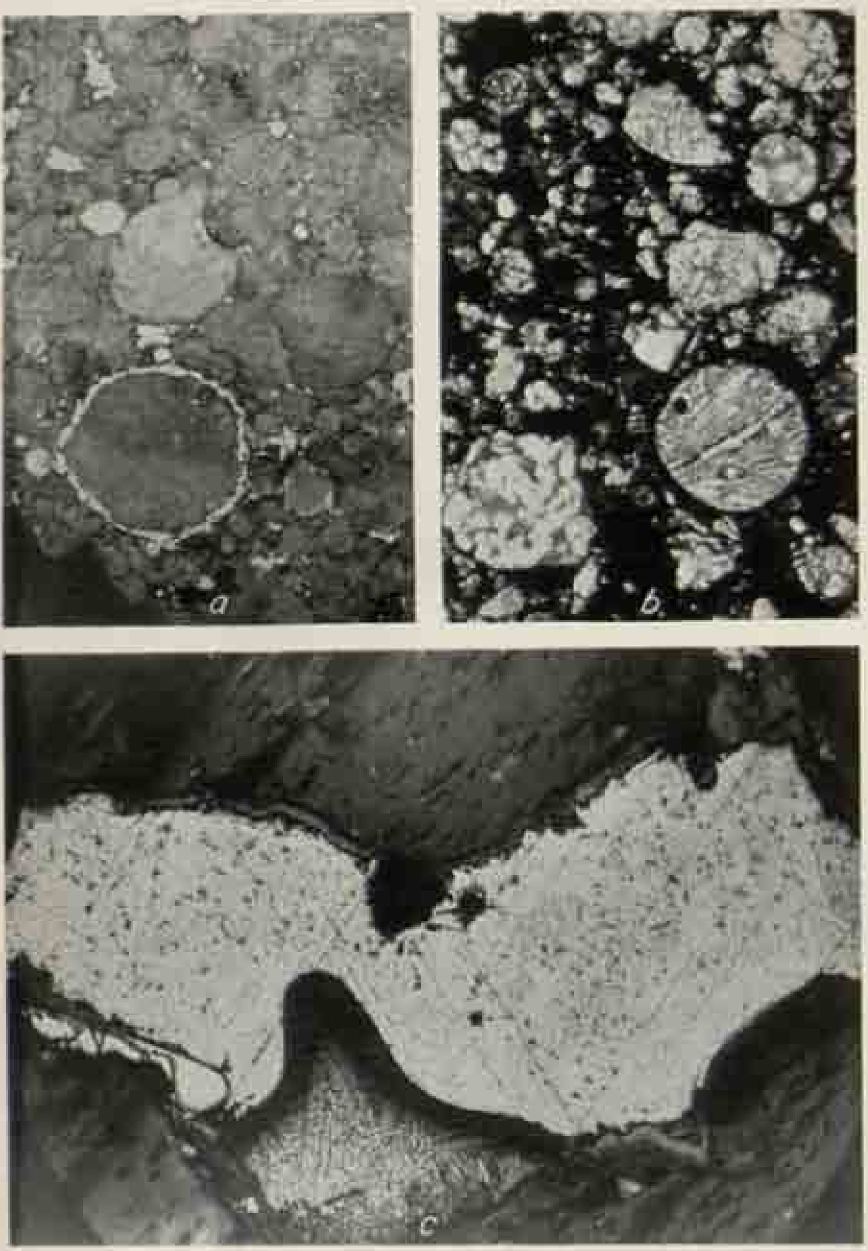
a, Bennett County, S. Dak. In addition to the two prominent sets of Neumann lines there is a third set making an angle of 85° with the nearly vertical lines. The dark elongated inclusion is troilite (sulphide of iron). b, the Negrillos mass of the North Chilean hexahedrite. The lower right-hand corner shows how these Neumann lines often control the weathering or disintegration of the mass, as the iron separates along these lines. Rounded inclusion of troilite interrupts some of the Neumann lines.



COARSE OCTAHEDRITE STRUCTURES.

Each area enclosed within the dark border has the Neumann lines, and in this respect the specimens are identical with hexahedrites. Some taenite may be present in these border zones, but it is often difficult to detect taenite in such specimens.

a, El Burro, Mexico (for composition see table 2); b, Sandia Mountains, N. Mex. (for composition see table 2).



METAL IN STONY METEORITES.

a, Tennasilm, Esthonia. Metallic constituents (lighter areas) form irregular rounded masses, also a halo around one chondrule. Obviously this iron formed much later than the chondrule and probably was introduced after the aggregate had formed. b, Sharps, Va. Complete chondrules and fragments of others are cemented together in a dark ground mass. Such structure resembles consolidated detrital material. c, Shallowater, Tex. The metal has a pearlitic texture which is apparently not interrupted by the Neumann lines. The dark embayment in from the bottom is filled with taenite, the upper dark area is a silicate, enstatite, containing 0.8 percent FeO. a and b, photographs by L. B. Hubbert.

PHILIPPINE TEKTITES AND THE TEKTITE PROBLEM IN GENERAL[1]

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One of several things for which the Philippines are remarkable is the presence in the Islands of the world's largest known deposit of tektites. The term "tektite" was adopted in 1900 by Prof. Franz E. Suess, of Vienna, as a general name for a curious group of natural glasses which have come to be widely regarded as of cosmic or extra-earthly origin. In recent times it has become apparent that these bodies did not fall singly or sporadically, but that great showers of them fell upon certain parts of the earth at widely separated geologic periods. A small deposit has been found in the Ivory Coast region of West Africa that is believed to date as far back as Mesozoic times; the Moldavites, or European tektites, date from the Helvetian strata of the mid-Miocene; the whole group of Far Eastern tektites, or Indo-Malaysianites, are undoubtedly mid-Pleistocene; while the Australites, or tektites of Australia and Tasmania, are believed to be post-Pleistocene or recent. These four major geologic groups of tektites all differ from one another to some extent in physical appearance, chemical composition, and specific gravity, but all possess certain common differences from other earthly rocks which have led them to be classed together as genuine tektites, of unknown but probably cosmic origin.

Most if not all true tektites appear to have been originally of the natural shapes that would be assumed by molten glass revolving in the atmosphere or any similar gaseous medium, i. e., spheroids, disks, or oval, cylindrical, dumbbell-shaped, and pointed, drop-shaped bodies, some later broken or exploded into fragments of various sizes. This fact, together with their anomalous chemical composition, and the further fact of their being found frequently in wholly nonvolcanic regions, have been the chief reasons for adopting the cosmic hypothesis

[1] Paper read at the seventh annual meeting of the Society for Research on Meteorites, Columbus, Ohio, December 1939. Reprinted by permission from Contributions of the Society for Research on Meteorites, Popular Astronomy, vol. 48, No. 1, January 1940.

in seeking a reasonable explanation of their origin. The Australite group of tektites adds still further probability to the cosmic theory by showing a partial re-fusing of the original glass sphere, a part of which has flowed backward and solidified into a more or less flattened ring or band, giving to the whole specimen a peculiar buttonlike appearance, in the typical forms. In many other cases, the re-fused material has been completely swept away in flight, leaving only a small sharp-edged or lens-shaped remnant of the original tektite sphere.

The Philippine tektites all belong to the general Indo-Malaysianite group, of mid-Pleistocene origin; this group contains also the tektites found in Indo-China, Borneo, and the Island of Java. While presenting great uniformity in composition, and in color, specific gravity, and other properties of the glass itself, the Indo-Malaysianites of different geographic areas present certain characteristic differences in shape, surface markings, flow-lines, and the degree of viscosity of the original material, which have led to their being divided into four major and several minor subgroups of more or less distinctive and well-defined character. The four major subgroups are:

1. *Indochinites* (originally most viscous, with stretched-bubble sections, and with both straight and curved pointed drops, and irregular fragments as the most characteristic forms, spheroids being rare).
2. *Rizalites* (pitted spheroids, ovals, and cylindrical forms being most characteristic, showing intermediate viscosity).
3. *Billitonites* and *Malaysianites* (with deeply etched spheroids, cylinders, and irregular pieces, showing worm-track grooves and navels as the characteristic forms; medium viscosity).
4. *Java tektites* (least viscous?, with highly complicated flow-lines mildly but clearly etched out on relatively smooth surfaces and with spheroidal and irregular or fragmentary forms as the most characteristic).

The most typical Indochinite specimens occur in South China and northern and central Indo-China, although they are found also, sparsely, in Luzon (particularly in the Rizal-Bulakan area, where they are mixed with much larger numbers of Rizalites and a few Billitonite and Malaysianite types).

The most typical Rizalites occur only in Luzon, although a few similar, pitted specimens are known from Borneo and Java.

The Billitonite and Malaysianite types, although least in number, cover the greatest area, being found in parts of southwestern Luzon, the Island of Busuanga in the west-central Philippines, Borneo, the Natuna Archipelago, southern Indo-China (especially Cambodia), the Malay Peninsula, and the Island of Billiton. The original Billitonites (first found in the tin mines of Billiton Island) show characteristic worm-track grooves and navels, with relatively smooth surfaces between such markings, while the true Malaysianites tend to show irregular and heavily etched surfaces with the irregular pits and other markings often running together more or less continuously, as seen most typically in many Cambodian and Busuanga tektites.

The most typical Java tektites are found only in central Java, but a few very similar specimens occur in the Philippines (particularly in the Santa Mesa district of Rizal Province).

The largest known whole tektites occur in southeastern Luzon, in the Paracale district of the Bikol Peninsula, while those of Indo-China rank next, and the Malaysianites probably third. The great Bikol tektites may be truly called "super-sized," since most of them are large, and small specimens comparatively scarce. The largest found so far weighs 1,070 g., and is an almost perfect sphere a little over 4 inches in diameter, but more than a hundred Bikol specimens running from 200 to 700 g. each have so far been found. The largest recorded whole Indo-China specimen is from Cambodia, and weighs 630 g., while the largest known Malaysianite is believed to have come from Pahang and weighs 464 g. Only a few other specimens weighing 300 g. or more are known, all of them having come from the Indo-Malaysianite region, most of them being from Indo-China and the Philippines, with one each from Java and the Malay Peninsula. The average for this region, however, is between only 15 and 20 g. The largest Australite has the exceptional weight of 218 g., since the Australites are the smallest of all tektites, averaging only about 1 g. each or less. Tektites from other regions are intermediate, but no recorded specimen reaches 150 g. in weight.

However, what was originally probably the most gigantic of all tektites is again recorded from Indo-China. This is the famous specimen of Lower Laos, of which several thousand irregular fragments have so far been gathered within a relatively small area. The largest piece weighs more than 3 kg., while many of the smaller ones weigh only a few grams each. The evidence to date seems to indicate that all of these pieces are parts of a single huge tektite, perhaps half a meter in diameter, and weighing nearly 100 kg. One of the most interesting things about these finds is that no other small whole tektites have been found anywhere near the same region; this fact lends force to the cosmic theory, since any shower of smaller bodies accompanying this great cosmic bomb would have tended to fall far behind in the course of its flight through the earth's atmosphere.

This brings us back again to the various theories accounting for the origin of the tektite glass itself. Many such theories have been propounded in the past, but most of them have been demolished by the extensive and often bitter criticism to which they have been subjected. A few theories, however, have withstood much critical discussion and are still worthy of serious consideration, although no single theory has yet received universal or wide acceptance among a majority of those interested in the major tektite problem and its solution. I shall conclude this paper by summarizing, first, the essential features of three views that are still being seriously con-

sidered and shall then present a new hypothesis that has recently been worked out on the basis of Philippine material and that seems to present certain features which will doubtless provoke much interesting discussion and may even add a new chapter to tektite history.

First, although no one has yet ever been able to present acceptable proof of the volcanic or other earthly origin of the tektite glasses, there is still an appreciable number of students of this question who believe that such an earthly origin will some day be demonstrated; therefore, this possibility should not be disregarded, although majority opinion is today decidedly against it.

Second, the view known as "the burning light-metal meteorite theory" (a theory developed in its various stages by Goldschmidt, Michel, Lacroix, and Suess) is still regarded by many capable investigators as the most acceptable explanation of tektite origin yet presented. In brief, this view is based on the generally accepted idea that the great seasonal meteoric showers which so frequently visit the earth's atmosphere, and are mostly wholly consumed in the upper air, consist in the main of the light metallic elements which oxidize at normal or relatively low temperatures. It is generally believed that a considerable amount of finely divided silica or siliceous matter is shed from such showers, probably reaching the earth usually as a fine powder or dust. This tektite theory presupposes that the earth has occasionally passed through abnormally thick clouds of such matter—such as, e. g., those which are commonly believed to form the tails of some comets, etc.—and that at such times the quantity of siliceous matter shed would be sufficient to form sizable globules of liquid glass, falling to the earth in solidified form as a tektite shower. (The principal objection to this view, in the mind of the present writer, is the difficulty of explaining the secondary re-fusing of the Australites and the absence of such secondary forms in the Indo-Malaysianites, since the glass of both types is of practically identical composition, color, and specific gravity. Van der Veen, however, has suggested that this difference was due to the more fluid nature of the Australite glass, while the Indo-Malaysianites were more viscous. The increasing viscosity of the Indo-Malaysianite glass, from Java northwestward to South China, seems to support Van der Veen's view.)

Third, Spencer's "meteorite explosion-crater" theory, while regarded as unacceptable by a majority of tektite students, is, in my opinion, still to be considered as a possible clue to the origin of many important varieties of pseudo tektites, etc., such as the silica glasses, Darwin glass, the Americanites, the Philippine pseudo Americanites of Santa Mesa and vicinity, the Claveria pseudo tektites, and possibly even the European Moldavites. The essentials of this view are, briefly: Quantities of silica glass of several types have been found

around such great known meteorite craters as those of Arizona, Wabar, Henbury, etc., and are believed to have been produced by the fusing of earthly rocks and sands by the terrific heat resulting from the explosive impact of the huge meteorites which produced such craters. An explosion great enough to produce a crater a mile or more in diameter would doubtless throw molten silica and other fused material a vast distance into the air, and such material would tend to assume the geometric forms common to glass drops, hardening as it fell back toward the earth. At the time of first propounding this view, in 1933, Spencer felt that the origin of tektites might be thus explained, but in his more recent writing he admits the difficulty of explaining the widespread Australites and Indo-Malaysianites on such grounds. The chief argument in favor of this view of tektite origin is that the composition of tektites approaches that of some earthly clays, but one would need to presuppose temperatures much higher and craters much vaster than any yet known on the earth. (However, we must await more detailed study of the great lunar craters, now coming to be regarded as mainly meteoritic in origin, and consider also the possibility that such great craters may have been destroyed or largely covered by erosion and vegetational growth on the earth.)

The present writer has expressed no personal opinion in favor of any of these theories of tektite origin, but has attempted merely to point out from time to time some of the arguments against or in favor of each of the views. The same attitude will be preserved as regards the new Rufus hypothesis presented herewith.

AN ASTRONOMICAL THEORY OF TEKTITES

Under this title Prof. W. Carl Rufus, of the Observatory and Astronomical Department of the University of Michigan, has presented to the writer a new explanation for the origin of tektites which was published in another paper.[3] For the present, I wish only, then, briefly to summarize the essentials of his theory here, and to advance a few short arguments for and against it. The essentials of the theory follow:

The small natural-glass bodies known as tektites were originally derived in major part from the glassy basalt, or tachylyte, which forms the deeper crustal layer of the earth, exposed chiefly on the floor of the Pacific basin, at the time of the fissional separation of the moon. Furthermore, the earthly tektites represent only a small section of the vast swarms of tiny satellites which remained revolving about the earth within the Roche limit and particularly that section of the satellites having a revolutional period closely coinciding with the

[3] Pop. Astron., vol. 48, No. 1, pp. 49–51, January 1940.

period of the earth's rotation. Such swarms would have remained approximately above the Pacific basin, but would have gradually fallen behind and tended to be drawn to the earth on account of perturbations resulting from the gradual retardation of the moon. Cumulative perturbations and other related factors have caused swarms of these bodies to come down to the earth at widely separated geologic periods in the earth's history, such falls having been particularly extensive along a great-circle route crossing the western edge of the Pacific basin. This condition would account for the great quantity and wide distribution of the Indo-Malaysian tektites especially, which are of almost identical chemical composition, while other showers of tektites came at different geologic periods and varied somewhat in composition and physical appearance.

While final critical appraisal of the theory must come from others better grounded in astronomical and geophysical knowledge than the present writer, there are certain implications of this new hypothesis that may well be pointed out. First, negatively, the well-known chemical differences between the true tektites and known earthly rocks have not yet been satisfactorily accounted for. It is true, perhaps that there are very few analyses of deep-seated glassy basalts available in our literature, and that this fact might account for the principal difference observed between the tektite chemical pattern and that of the more widely known surface rocks (either plutonic or volcanic). In particular the dominance of potash over soda in the tektites is outstanding, and is accompanied usually by a predominance of ferrous oxide. This condition is just the opposite of that of most known earthly rocks and glasses, and it is obvious that further evidence is needed here.

It should be noted, however, that the foreging objection applies with equal force to all other proposed tektite theories, except the generalized cosmic hypothesis. On the other hand, the Rufus theory explains or lends important support to a number of other views hitherto regarded as not altogether acceptable in their entirety; e. g., Fenner's views as to the origin of the secondary forms of the Australites fit in very well with the Rufus theory; in fact the Australites furnish probably the best support for the new theory, although they almost certainly represent a different shower from that which gave us the Indo-Malaysian tektites. The larger and heavier Indo-Malaysian tektites would have been drawn down at an earlier period than the smaller and lighter Australites, although the glassy substance of which both are formed is of almost identical chemical composition.

Past experience has shown that it is easier to demolish tektite theories than to find substantial support for any one of them. Professor Rufus has thus been rightly cautious in presenting his new explanation, and in welcoming expected criticism and discussion. It is

hoped that constructive criticism by qualified contemporaries may soon demonstrate whether or not this latest explanation of tektite origin can stand the test and take its place among the few most acceptable theories accounting for these strange bodies.

POSITION OF THE PHILIPPINES IN RELATION TO TEKTITE STUDIES

Up to last year, the present writer and Dr. Siguel Selga, S.J., of the Weather Bureau, were the only local students to take a serious interest in tektite studies, but, since the middle of 1938, Mr. J. Van Eck, of the Marsman staff in Paracale, has been making some very interesting observations on the physical history and characteristics of the Bikol tektites. A monograph by the writer, covering the results of some 12 years' active study and collecting of Philippine tektites, since the first specimen was found in 1926 in a Rizal Province archeological site, will be ready shortly for publication. However, in view of the unique opportunity that the Philippines present for the study of the richest known deposits of tektites in their natural environment, it is to be hoped that other local scientists may soon take a greater interest in this subject; and it is with the hope of stimulating such interest that I am presenting the present outline of the subject at this meeting and to the Phiilppine National Research Council.

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CHEMICAL PROPERTIES OF VIRUSES[1]

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[With 6 plates]

Six years ago over a hundred viruses were recognized, yet it would have been virtually impossible to write then on the present subject, for at that time practically nothing was known about the chemical properties of viruses. These agents, which are responsible for untold millions of illnesses and deaths amongst people, animals, and plants, were recognized only by means of the diseases which they caused, diseases such as smallpox, parrot fever, yellow fever, St. Louis encephalitis, poliomyelitis, horse encephalomyelitis, foot-and-mouth disease of cattle, louping ill of sheep, hog cholera, rabies, dog distemper, fowl pox, certain types of tumorous growths in fowls and other animals, jaundice of silkworms, and various yellows and mosaic diseases of plants. The general nature of the agents responsible for such diseases was a matter of much conjecture. When placed in certain living cells, these agents could multiply, mutate or undergo variation to form new strains, and induce immunity. They seemed to have many of the properties of very small living organisms such as the bacteria; yet, unlike most bacteria, they were too small to be seen by means of the ordinary microscope and could not be induced to multiply in the absence of living cells. They were mysterious, invisible somethings which, in the absence of living cells, appeared as harmless and as lifeless as pebbles on the beach, but which, even after years of inactivity, were ready to spring into action and cause disease and death when introduced by chance or by design into certain living cells. By virtue of their ability to mutate or form variants, they were able to change and adapt themselves to new surroundings and conditions and thus not only to retain but to enlarge their place in a changing world. The fact that the viruses were recognized only by means of the diseases which they caused and the fact that these diseases were becoming of increasing importance only served to add

[1] Reprinted by permission from The Scientific Monthly, vol. 53, September 1941.

to the mantle of mystery which surrounded them and to intensify the challenge which they presented.

In 1935 a tangible characteristic material possessing virus activity was isolated from Turkish tobacco plants diseased with tobacco mosaic virus and made available for chemical study. The material, which appeared to be a nucleoprotein of enormous size possessing quite distinctive properties, was obtained from every lot of diseased Turkish tobacco plants examined. The same material was obtained from various, in some instances unrelated, species, of mosaic-diseased plants. Slightly different, although closely related, nucleoproteins were isolated from plants diseased with strains of tobacco mosaic virus. The purified preparations possessed properties which were characteristic, not of the hosts in which they were produced, but of the virus or virus strain. An unexpected finding was that mosaic-diseased Turkish tobacco plants may contain as much as 1 part per 500 of the high molecular weight nucleoprotein. The amount of material isolable varied in other cases and appeared to depend upon the host and the strain of the virus, and in some instances was only a small fraction of the amount obtainable from mosaic-diseased Turkish tobacco plants. To date all attempts to separate tobacco mosaic virus activity from the nucleoprotein have failed and the material, which can be obtained in the form of long thin paracrystalline needles (pl. 1, fig. 1), has come to be regarded as crystalline tobacco mosaic virus. The material provided the first information regarding the general nature and chemical makeup of this virus and, although its exact nature was and remains a debatable matter, its isolation removed some of the mystery surrounding the general nature of viruses and served as an incentive for the search for similar materials in the case of other virus diseases.

The isolation of crystalline tobacco mosaic virus was followed by the preparation from various virus-diseased tissues of over 20 crystalline or amorphous materials possessing some of the properties of the respective viruses or virus strains. In not every case has it been proved that the material is essentially pure and consists of virus. However, in several cases it has been proved beyond a reasonable doubt that the materials consist of the respective viruses in an essentially pure state, and in no instance has virus activity been obtained in the absence of the characteristic material. Owing chiefly to our older ideas of the nature of viruses, the crystallinity of some of the purified preparations may appear at first as a rather spectacular property; yet, if these materials are considered as proteins, crystallinity becomes an expected rather than an unexpected property, for many proteins are known to be crystallizable. Careful and mature consideration will reveal that crystallinity or the lack of crystallinity is of no special importance in connection with the purity or general

nature of a material, but is important chiefly because it makes it possible to obtain certain solubility and X-ray data which would otherwise be unobtainable.

There is not sufficient space for a detailed discussion of the chemical properties of all the preparations of purified viruses and, in order to provide you with an idea of their general chemical properties, I shall devote most of the text to the two viruses which have been extensively investigated from this standpoint, namely, tobacco mosaic and tomato bushy stunt viruses. These are typical viruses with respect to the essential and recognized characteristics of a virus; yet it must be admitted that each has certain special properties which make it an unusually favorable material for experimental work. Thus, tobacco mosaic virus is among the most stable of all viruses and reaches a concentration in Turkish tobacco plants which is far greater than that reached by most viruses in their respective hosts even under the most favorable conditions, and bushy stunt is the only virus that has been obtained in the form of large rhombic dodecahedric crystals (pl. 1, fig. 2). However, there is no more reason for regarding these viruses as atypical because of such special properties than for regarding vaccine virus as atypical because of its unusually large size, or foot-and-mouth disease virus as atypical because it is the smallest of all viruses. Tobacco mosaic and bushy stunt are plant diseases, and it has been argued that the viruses of plants differ fundamentally from those of animals and, hence, that information gleaned from studies on plant viruses has but little significance in connection with animal viruses. This argument was based chiefly on the failure of plant viruses to grow in animals and of animal viruses to grow in plants. However, because there is no difference in the fundamental virus properties, I have always considered this to be an erroneous viewpoint. Within the past few years, Fukushi secured strong evidence that rice dwarf disease virus multiplies in its insect vector, and Kunkel and more recently Black have obtained experimental evidence which demonstrates beyond a reasonable doubt that aster yellows virus can multiply in its insect vector. The growth of a plant virus in an animal provides further evidence in support of the conclusion that there is no fundamental difference between the viruses of plants and those of animals. Different viruses must of necessity differ in certain of their properties, and a composite picture of viruses as a group will not be obtained until many viruses have been studied.

Tobacco mosaic virus appears to be a conjugated protein containing about 95 percent protein and 5 percent nucleic acid. The latter has been found to contain uridylic acid, guanine, cytosine, and adenine, and to give a test for a pentose but not for a desoxypentose and, hence, appears to be of the yeast rather than of the thymus nucleic

acid type. Bushy stunt virus appears to contain about 83 percent protein and 17 percent of a nucleic acid of the same kind as that found in tobacco mosaic virus. Tobacco ring spot virus contains 40 percent nucleic acid, the highest percentage yet found in a virus. This is also of the yeast nucleic acid type, but the elementary bodies of vaccinia and of psittacosis have been found to give a test characteristic of thymus nucleic acid. With the exception of a bacteriophage preparation obtained by Kalmanson and Bronfenbrenner and considered to be a simple protein, all the purified virus preparations so far obtained have been at least as complex as a nucleoprotein. This fact may eventually prove of prime importance, for it may be recalled that chromosomes appear to consist almost exclusively of nucleoprotein. Some viruses appear to contain in addition some carbohydrate, others lipoid, and still others appear to be so complex that they may be indistinguishable from bacteria in composition. The distribution of amino acids in the protein component of tobacco mosaic virus has been studied, and at present only the apparent absence of histidine and the lack of a preponderance of arginine and of other known basic amino acids are noteworthy. The complete amino acid distribution in strains of this virus and in other viruses has not been determined as yet, although such studies are in progress and may provide a clue to the reason for the specificity of viruses and possibly a means for distinguishing not only between viruses but also between the strains of a virus. For example, with Dr. Knight it has already been found that the amounts of certain aromatic amino acids vary with the strain of the virus. Analysis of 12 preparations of tobacco mosaic virus indicated the presence of 3.8, 4.5, and 6.0 percent of tyrosine, tryptophane, and phenylalanine, respectively, with maximum deviations of ± 0.1 percent for the tyrosine and ± 0.2 percent for the tryptophane and phenylalanine values. The corresponding values in the case of the Holmes ribgrass strain of tobacco mosaic virus were 6.4, 3.5, and 4.3 percent and 3.8, 1.4, and 10.2 percent in the case of the closely related cucumber mosaic virus 4. These results are of considerable importance, since they show that the mutation of tobacco mosaic virus with the formation of a new strain which in turn causes a new disease may be accompanied by changes in the amino acid composition of the virus. The fact that the phosphorus content of the different strains was approximately the same may be taken as an indication of the absence of significant quantitative differences in the nucleic acid component of the strains. Because of the close similarity between the properties of viruses and those of the bearers of heredity, it is obvious that an extension of this work should provide information of a fundamental nature regarding the structural changes involved in the mutation within chromosomes. The nature of the structural alterations which must

be responsible for changes in the virulence of a virus may also be elucidated.

Tobacco mosaic virus contains 50 percent carbon, 7 percent hydrogen, 16 percent nitrogen, 0.6 percent phosphorus, and 0.2 percent cysteine sulfur. It has an isoelectric point at pH 3.5, a density of 1.37, and at a concentration of about 2 mg. per cc. a sedimentation constant of 174×10^{-13} cm. in unit centrifugal field and a diffusion constant of 3×10^{-8} sq. cm. per sec. It has been estimated by indirect methods that the particles of the virus are remarkably anisometrical and are about 400 mμ in length and about 12 mμ in diameter. Recently, by direct observation by means of the electron microscope, Dr. Anderson and I found that most of the particles in a dilute solution of the virus are about 280 mμ in length and about 15 mμ in diameter (pl. 1, fig. 3). Several kinds of evidence indicate that the molecular weight of tobacco mosaic virus is about 50 millions. The value of 17 millions, which was estimated several years ago when the asymmetry was unknown and which was based on an assumed asymmetry constant of 1.3, is incorrect. However, it is possible that different strains of tobacco mosaic virus may have different molecular weights, for the sedimentation constant of the aucuba mosaic strain is measurably larger than that of tobacco mosaic virus and the X-ray data indicate that the molecules of the former have the same diameter as that of the molecules of tobacco mosaic virus. Furthermore, Melchers and coworkers, in a study by means of the electron microscope, found the molecules of the two strains of tobacco mosaic virus with which they worked to have particle lengths of about 190 mμ and 140 mμ.

Tobacco mosaic virus gives a sharp boundary and migrates at a uniform rate in the Tiselius electrophoresis apparatus (pl. 2, fig. 1). When carefully prepared, the virus gives a sharp boundary in the ultracentrifuge, but on treatment with salt at room temperature some of the particles appear to aggregate end-to-end to give a preparation which shows two boundaries in the ultracentrifuge. The second more rapidly sedimenting boundary is due apparently to a component formed by the end-to-end aggregation of pairs of molecules (pl. 2, fig. 2). Further aggregation yields a very inhomogeneous product which shows a very broad boundary in the ultracentrifuge. The sedimentation constant of tobacco mosaic virus has been found to vary with the concentration, owing apparently to interparticle forces which become of considerable magnitude in concentrated solutions. Solutions of tobacco mosaic virus exhibit strong double refraction of flow and electrical double refraction, the former being due to the rodlike shape of the particle and the latter to the particle being asymmetrically charged, either permanently or as a result of the electrical field (pl. 2, fig. 3). The fact that tobacco mosaic

virus shows strong double refraction of flow may prove of considerable importance in apparently unrelated fields, for if necessary the virus could be prepared in pound lots or in larger amounts and used to study the flow currents in apparatus such as pumps and hydraulic rams or the nature of the flow when boats or projectiles move through a liquid (pl. 3, figs. 1 and 2). Moderately concentrated solutions of the virus, when allowed to stand, separate out into two distinct layers, the lower of which is spontaneously doubly refracting and the upper of which shows double refraction only when caused to flow. Pellets of the virus obtained by ultracentrifugation are doubly refracting. The strains of tobacco mosaic virus and cucumber mosaic 3 and 4 viruses have properties somewhat similar to those just described. Latent mosaic virus of potato has a rodlike shape and appears to be even more asymmetrical than tobacco mosaic virus. The layering phenomenon, the change in sedimentation constant with concentration, and certain of Bernal's X-ray studies, of Lauffer's observations on the electro-optical effect, and of Frampton's studies on the thixotropic character of tobacco mosaic virus indicate that in concentrated or moderately concentrated solutions there are interparticle forces which are effective over large distances. Although in the past the existence of such long-range forces has been denied for theoretical reasons, Langmuir and Levine independently have recently shown that there are in fact good theoretical grounds for their existence. The demonstration of the existence of forces acting between molecules hundreds of Å. units apart, and their acceptance from the standpoint of theory alone, may prove of great importance in connection with our theories of virus reproduction and other intracellular events such as the duplication of chromosomes.

The carbon, hydrogen, and nitrogen contents of bushy stunt virus are about the same as those of tobacco mosaic virus. However, the phosphorus and sulfur contents of 1.5 and 0.4 to 0.8 percent, respectively, are considerably larger than those of tobacco mosaic virus. Bushy stunt virus has a density of 1.35, a sedimentation constant of 132×10^{-13}, and a diffusion constant of 1.15×10^{-7}. A molecular weight of about 8 million and a particle diameter of about 26 $m\mu$ may be calculated from these constants. Solutions of bushy stunt virus do not show double refraction of flow and the pellets obtained on ultracentrifugation are isotropic. The particles of the virus appear to be essentially spherical in shape. The purified preparations are homogeneous when examined in the ultracentrifuge or the Tiselius electrophoresis apparatus (pl. 3, fig. 3). Bushy stunt virus does not appear to be susceptible to the peculiar aggregation which seems to be a characteristic of the rod-shaped viruses and, unlike the latter, the sedimentation constant is almost independent of the concentration. Several other viruses have been found to be essentially spherical in shape.

Among these are alfalfa mosaic virus, which has a molecular weight of about 2 million and a diameter of about 16 mμ, and the Shope rabbit papilloma virus, with a molecular weight of about 25 million and a diameter of about 40 mμ. The elementary bodies of vaccinia have a diameter of about 225 mμ. There is, therefore, a group of rod-shaped viruses and a group of viruses which are essentially spherical in shape, although with the development of more precise techniques some of the latter may be found to be definitely ellipsoidal in shape. It should be emphasized that each virus has a shape and a size which appear to be quite definite and characteristic, regardless of the conditions or the host in which the virus is produced. However, neither this statement nor the statements relative to the homogeneity of virus preparations in the ultracentrifuge or electrophoresis apparatus are meant to imply that all the particles in a given virus preparation are exact replicas. The fact that variants continually arise during the production of virus would always insure the presence in purified preparations of a small amount of closely related although slightly different particles. There is other evidence, such as that obtained by Loring in solubility studies on tobacco mosaic virus, which indicates that the purified virus preparations are not absolutely homogeneous chemically but consist of a family of very closely related structures. The general situation may not be far different from that which is now known to exist in the case of even very simple structures, such as sulfur, nitrogen, and hydrogen, where families of isotopes are the rule rather than the exception. In this connection, it may be stated that the problems and relationships which obtain with the tremendous virus structures are not well clarified at present. However, from a practical standpoint, there has been little difficulty as yet, for there are several instances in which, according to present techniques, there is a very high degree of chemical homogeneity.

Tobacco mosaic, bushy stunt, and other viruses which have been obtained in purified form are good antigens. It is necessary, however, to inject animals with the viruses, for antibodies do not appear to be produced in plants. This may be due to the nature of plants for, despite much effort, no conclusive proof of the existence of antibodies in plants has been obtained, although Wallace secured some suggestive results with curly top virus. The serum of a rabbit injected with tobacco mosaic virus gives a specific precipitate with tobacco mosaic virus and specifically neutralizes tobacco mosaic virus activity. This reaction has been studied with Dr. Anderson by means of the electron microscope and the ultracentrifuge. Electron micrographs of a mixture of virus and normal rabbit serum show virus particles of normal size, indicating little or no adsorption of particles from normal serum on the virus molecules (pl. 4, fig. 1). The sedimentation constant of tobacco mosaic virus is essentially unchanged in mixtures containing

normal rabbit serum or antisera to bushy stunt, ring spot, or latent mosaic viruses. However, electron micrographs of a mixture of tobacco mosaic virus and tobacco mosaic virus antiserum from rabbits show particles about 60 mμ wide, about 300 mμ long and having fuzzy profiles (pl. 4, fig. 2). The increase in particle width and the fuzzy appearance are regarded as indicating that the ends of asymmetrically shaped molecules from the serum react specifically with the virus molecules. No reaction between anti-tobacco mosaic virus serum and bushy stunt virus was demonstrable either by means of the electron microscope or the ultracentrifuge (pl. 5, fig. 1). Bushy stunt virus is, however, specifically precipitated by its own antiserum (pl. 5, fig. 2). In general, a serological relationship may be demonstrated between different strains of the same virus, but not between different viruses. However, Bawden and Pirie have found that a serological relationship exists between tobacco mosaic and cucumber mosaic 3 and 4 viruses. This fact and the fact that other properties of these viruses are very similar may indicate a common origin for these viruses. Bawden and Pirie also noted that the precipitates of rod-shaped viruses with their antisera resembled those obtained with bacterial flagellar antigens, whereas those of the symmetrically shaped bushy stunt virus resembled those with somatic antigens. Tobacco mosaic virus has been found not anaphylactogenic by the Schultz-Dale technique and only weakly anaphylactogenic when tested *in vivo*.

Viruses are inactivated when subjected to excessive amounts of acid, alkali, oxidizing agents, formaldehyde, urea, ultraviolet light or heat. In general, the rate and the amount of the inactivation vary with the virus and with the severity of the treatment. Tobacco mosiac virus is stable between about pH 2 and pH 8. At more acid or more alkaline reactions the nucleoprotein is denatured and broken up into material of low molecular weight, and the virus activity appears to be irreversibly lost. There is some evidence that the virus first breaks into fairly large pieces and these then continue to break up into progressively smaller pieces, but more data will be required before an exact picture of the process may be obtained. The disintegration of virus in urea provides another interesting process for study. In 6 M urea and 0.1 M phosphate buffer at pH 7, tobacco mosaic virus is rapidly disrupted, with appearance of free sulfhydryl groups, into low molecular weight protein components which contain no nucleic acid, exhibit no double refraction of flow, are insoluble in dilute buffers, and possess no virus activity. The rate of the disintegration varies widely with the concentration of urea, the concentration of electrolyte, the type of electrolyte, the hydrogen-ion concentration and the temperature. The bonds which hold the component parts of the virus together appear to be released and satisfied by those of the urea, for the virus structure literally flies apart.

It is obvious that studies on these split products should reveal information concerning the nature of the components making up the virus and perhaps furnish a clue as to the mode of synthesis of the virus. Materials similar in structure to urea, such as guanidine, as well as apparently unrelated substances, such as sodium dodecyl sulfate, also cause disintegration of the virus. Enzymes have been found to cause the break-up of certain viruses. Neither tobacco mosaic nor bushy stunt virus is split by trypsin, but this enzyme causes the rapid hydrolysis of alfalfa mosaic virus. Tobacco mosaic virus appears to be digested slowly by pepsin, although the rate of hydrolysis is much slower than might have been anticipated. All viruses appear to be denatured by heat, and the temperature at which denaturation occurs depends upon the virus and to some extent upon conditions such as the hydrogen-ion concentration and the kind of salts present.

In the heat and other types of denaturation reactions that have just been described, there is a more or less complete disintegration of the virus structure and the products which are formed do not have the properties which characterized the intact virus. They are of low molecular weight, do not react serologically with antiserum to virus, and do not induce the formation of antibodies which neutralize virus. It has been found possible, however, to inactivate viruses without such a complete disintegration of structure. When tobacco mosaic virus is treated with mild oxidizing agents, formaldehyde, nitrous acid, or ultraviolet light, the properties of the resulting materials are, with the exception of virus activity, very similar to those of the intact virus. For example, the size and shape are not measurably affected, the materials give a precipitin reaction with antiserum to active virus, and, perhaps most important, the injection of the inactive materials gives rise to the production of antibodies which will specifically neutralize tobacco mosaic virus activity. It appears that these treatments cause no great change in the general topography of the virus structure, but bring about changes that are very small with respect to the structure as a whole but which are nevertheless sufficiently definite to cause the loss of virus activity. This fact may be quite important in connection with efforts to protect ourselves against the devastating effects of virus diseases. As you may know, in the three general methods of protection which are now employed, active virus plus immune serum, active virus usually of a strain that will cause a less severe disease, or inactivated virus is used to secure immunization. The second method is used extensively and successfully in the protection against smallpox, yellow fever, and certain other virus diseases, and the third method, which has proved less satisfactory, has been used with claims for success for many viruses such as hog cholera, rinderpest, dog dis-

temper, influenza, and others. It is now being widely employed in the case of equine encephalomyelitis virus. In the second method, the production of a strain which will cause an innocuous disease but which will immunize against virulent strains is most important. In the third method, the production of an inactivated virus which will, upon injection, immunize against active virus is most important. It seems likely that many of the failures to achieve the latter result have been due to the use of methods of inactivation which cause too great a change in the structure of the virus. In our studies of the viruses which we have purified, we have found that the same procedure which will inactivate a given virus without causing widespread loss of structure and loss of characteristic antigenic properties will cause the complete disintegration and loss of characteristic antigenic properties in another virus. It is obvious, therefore, that it is of extreme importance that viruses be obtained in purified form and studied so that for each virus a method may be evolved for inactivating the virus without destroying its immunizing potency. The change in structure that results in inactivation need not necessarily be very great, and it may even be reversible. For example, we have found that the inactivation resulting from the addition of formaldehyde to tobacco mosaic virus may be reversed and active virus once again prepared from the inactive material. The fact that this reaction may be reversed is some indication that a major change in structure is not involved.

Closely related to the general problem of inactivating viruses with the least possible change in structure are the studies on ways and means of producing the less virulent strains of a virus which are so important in connection with the second general method of immunization. So far, the production of less virulent strains which have proved of great practical importance has been achieved by the simple expedient of passing the virus through another host. Thus, a strain of virus which will protect against smallpox may be obtained by infecting a calf with smallpox virus and reisolating the virus produced after several passages in calves. A useful strain of yellow fever virus was secured in a similar manner by Theiler by passage through mouse brains. The change in environment during the production of virus in the second host apparently results in the production or selection of a strain of virus which is much less virulent in the first host. Practically nothing is known as to why a less virulent strain is prepared or of the change in structure which must be involved. However, it does not appear unreasonable to expect that definite chemical reactions which result in a change in the structure of a given virus without causing inactivation will achieve the same result and yield strains of the virus, some of which may cause a less virulent disease and be useful for immunization against virulent strains. Leaves diseased with different strains

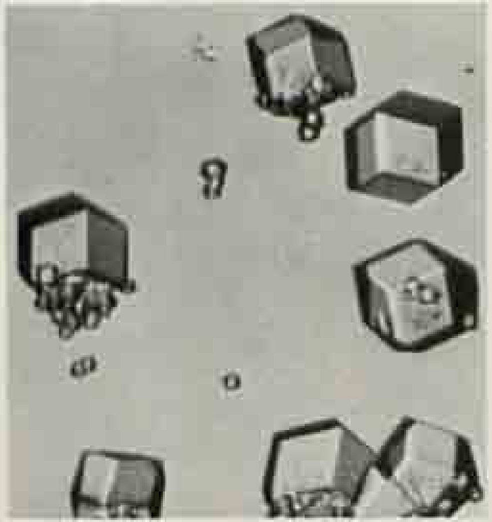
of tobacco mosaic virus are shown in plate 6. Some progress has been made in studies on methods for changing the chemical structure of tobacco mosaic virus without causing a loss of virus activity. Dr. Anson and I found that the sulfhydryl groups of the virus can be abolished by reaction with iodine and the altered virus still retains its normal biological activity as shown by the number of lesions it causes on *Nicotiana glutinosa* plants and by the characteristic disease produced in Turkish tobacco plants. Since the virus isolated from the latter plants had the normal number of sulfhydryl groups, the structural change caused by iodine treatment was not perpetuated in subsequent generations of the virus. Because of the possibility that the iodine-altered virus might be reduced to normal virus within the plant cells, other reactions of a less readily reversible nature were sought. With Dr. Miller it was demonstrated that most of the amino groups of tobacco mosaic virus may be acetylated by means of ketene without causing a measurable change in the specific virus activity or in the nature of the disease produced in Turkish tobacco plants. Since it seems unlikely that the acetyl groups are removed on inoculation of the modified virus to plants, the fact that the virus produced in such plants contains the normal amount of amino nitrogen may be regarded as evidence that the modified virus actually brings about the production of normal or unmodified virus. Similar results have been obtained with virus modified by the introduction of about 3,000 phenylureido groups per molecule of virus by means of reaction with phenylisocyanate. These results demonstrate that a large portion of the surface structure of the virus may be changed without interfering with the basic reaction of virus reproduction. Other reactions are being studied in an effort to secure modifications that will be perpetuated in subsequent generations of the virus. The purposeful production of new and useful strains by chemical means is one of the major problems in the virus field and its solution will be of tremendous importance not only from a practical standpoint but also in connection with the larger and fundamental problem of the nature of virus activity. The latter problem, the inactivation problem and the problem of induced mutation are all so closely related that it is impossible to attack one without attacking the others and simultaneously fundamental problems in other fields, such as the origin of a cancerous cell, the duplication of a chromosome, the mutation of a gene, and even perhaps the nature of that ill-defined something called life.

Although we do not know how viruses originate, reproduce, or mutate, we have learned much about their chemical properties during the past 5 years. We know that for every reasonably stable virus which has been investigated there is a definite, characteristic, high molecular weight material which is at least as complex as a nucleo-

protein. The properties of these materials may differ widely, although in each instance the size, shape, and chemical and other properties are the same regardless of the source of the virus. The properties of materials from strains of the same virus are similar although slightly different. The amounts of the materials that may be obtained differ tremendously and appear to depend upon the host and the virus or virus strain. The materials appear to be reasonably homogeneous when carefully prepared. Many different types of experiments have demonstrated a direct correlation between the integrity of structure of a given material and its virus activity. Because of this and because it has not been found possible to separate virus activity from these materials, there is reason to believe that they are the viruses. They appear to have the properties of molecules and in addition the property of virus activity, a kind of property usually assigned to organisms and one which has not heretofore been ascribed to molecules. Some may wish to consider that there is a sharp line of division between molecules and organisms and that viruses belong wholly in one or the other of these two groups. Others may wish to retain the sharp line of division but place some viruses in one group and other viruses in the second group. However, to a chemist it appears preferable to consider that virus activity may be a property of molecules, that there may be no sharp line of division between molecules and organisms, and that the viruses may provide the transition between the two. One virus has been inactivated and reactivated, and some idea gained of the accompanying change in structure. Studies on the elementary composition, the amino acid distribution, the amount and kind of nucleic acid, the immunological reactions, the effect of different enzymes, the pH and thermal stability ranges, and the effect of many different kinds of chemicals have been completed on some of the viruses. Extensive studies of the physical properties have also been made and the existence of long-range forces between molecules has been demonstrated. There is every reason to believe that the extension of these studies will eventually result in the solution of the more fundamental problems related to the viruses, such as the nature of their origin, reproduction, and mutation.

1. TOBACCO MOSAIC VIRUS.

Each needlelike crystal contains many molecules of virus and has been referred to as para-crystalline, since X-ray data indicate a lack of intermolecular regularity in the direction of the length. Magnification × 675.

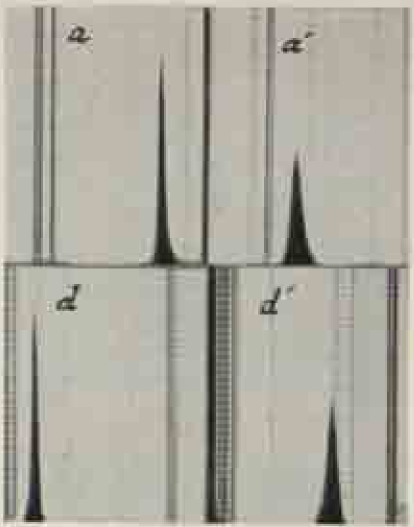


2. TOMATO VIRUS.

Crystals of tomato bushy stunt virus. Magnification × 200.

3. TOBACCO VIRUS MOLECULES.

Micrograph of molecules of tobacco mosaic virus taken by means of the RCA electron microscope. Magnification × 35,000. (From Journal of Biological Chemistry.)



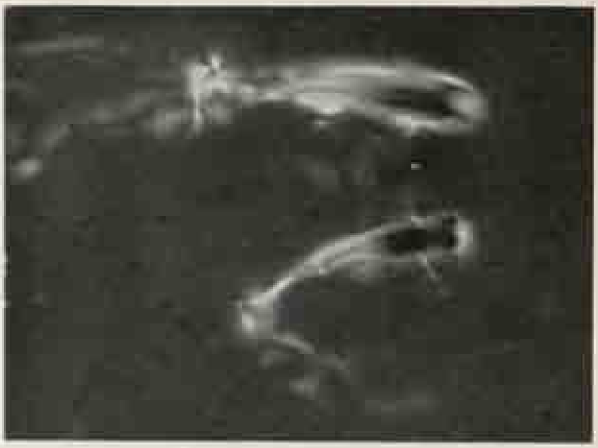
1. ELECTROPHORETIC PATTERN.

Shown by a 0.1 percent solution of tobacco mosaic virus. *a* and *d* represent the ascending and descending boundaries at the start of the experiment. *a'* and *d'* represent the same boundaries at the end. (By G. A. Miller.)

2. ABSORPTION PICTURES OF TOBACCO MOSAIC VIRUS SHOWING TWO SHARP SEDIMENTING BOUNDARIES.

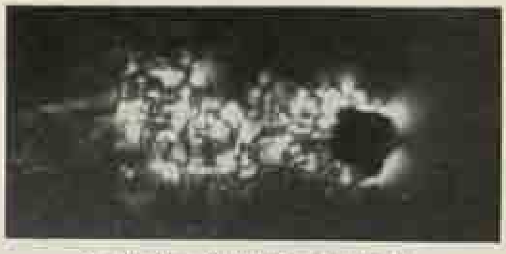
3. DOUBLY REFRACTING STREAM OF TOBACCO MOSAIC VIRUS FLOWING FROM A PIPETTE.

Left, photographed between crossed polaroid plates arranged so that each vibration direction of the polaroid plates makes an angle of 45° with direction of flow. Right, same system photographed between parallel polaroid plates. (From Journal of Biological Chemistry.)



1. FISH IN VIRUS SOLUTION.

Fish swimming through a 0.7 percent solution of tobacco mosaic virus. Photographed between crossed polaroid plates. Light areas show double refraction due to orientation of rodlike molecules of virus caused by current set up by movement of fish. (By J. A. Carlile.)



2. OBJECT IN VIRUS SOLUTION.

Object moving from left to right through a 0.7 percent solution of tobacco mosaic virus. Photographed between crossed polaroid plates. Light, doubly refracting areas show nature of currents caused by moving object. (By J. A. Carlile.)

3. SEDIMENTING BOUNDARY.

Absorption pictures showing sedimenting boundary of tomato bushy stunt virus.

1. MIXTURE OF TOBACCO MOSAIC VIRUS WITH NORMAL RABBIT SERUM.

The contaminating bacterium serves to give a good idea of the relative size of the molecules of virus. Electron micrograph with magnification × ca. 25,000. (From Journal of Biological Chemistry.)

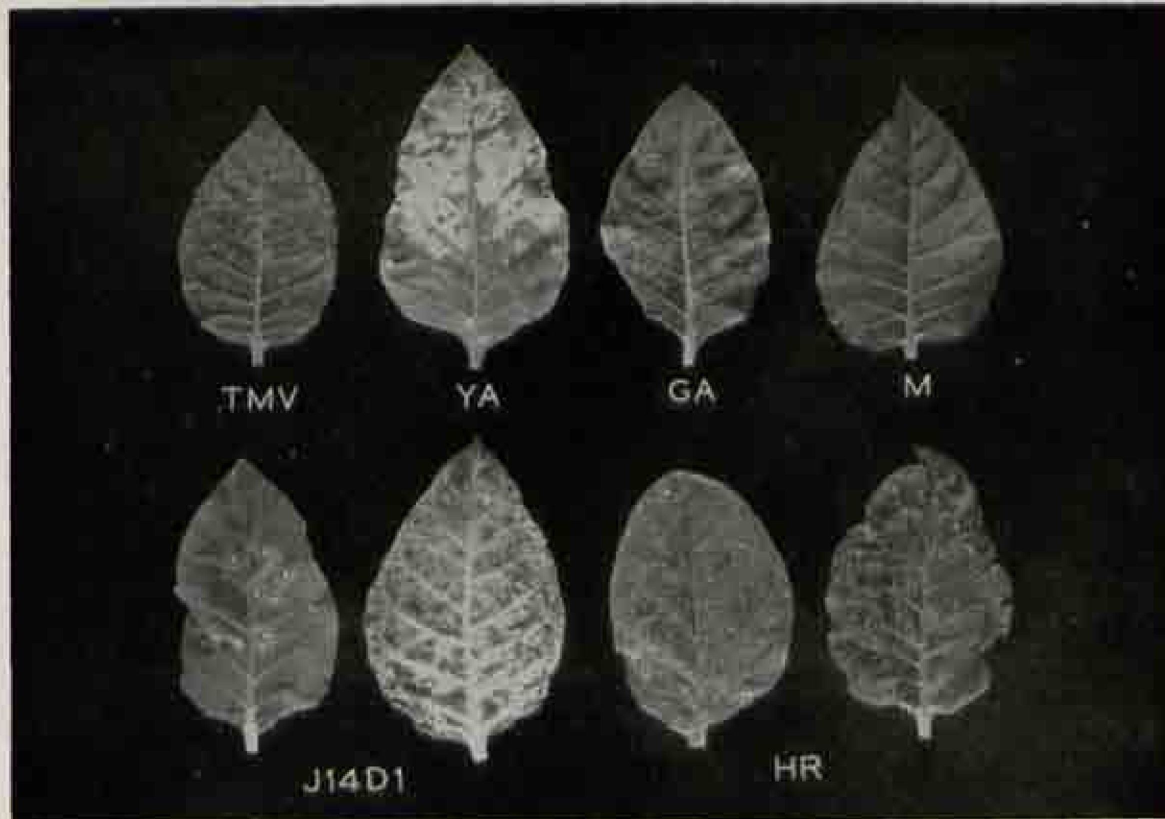
2. TOBACCO VIRUS WITH ANTITOBACCO VIRUS RABBIT SERUM.

An electron micrograph with magnification × ca. 30,000. (From Journal of Biological Chemistry.)

1. Sedimentation diagram of a mixture of tomato bushy stunt virus with antitobacco mosaic virus rabbit serum. At the centrifugal force used, the right-hand peak, which is due to the serum protein boundary, is practically stationary, whereas the other peak, which is due to the bushy stunt virus boundary, gradually moves to the left. The sedimentation constant of the bushy stunt virus is essentially unchanged, indicating lack of reaction with the antiserum.

2. MIXTURE OF VIRUSES.

Electron micrograph of a mixture of tobacco mosaic and bushy stunt viruses with antibushy stunt virus rabbit serum. The molecules of tobacco mosaic virus are unaffected; those of the bushy stunt virus are clumped together. Magnification × ca. 14,000. (By T. F. Anderson and W. M. Stanley.)



LEAVES OF TURKISH TOBACCO PLANTS SHOWING SYMPTOMS TYPICAL FOR EACH OF SIX STRAINS OF TOBACCO MOSAIC VIRUS.

TMV tobacco mosaic virus, YA yellow aucuba; GA green aucuba; M Holmes' masked strain; J14D1 a derivative, isolated by Dr. L. O. Kunkel, of Dr. J. H. Jensen's J14 virus; and HR Holmes' ribgrass strain. The leaf showing the masked strain (M) is practically indistinguishable from a normal leaf, although it contains an appreciable amount of virus. The J14D1 and HR viruses differ from the other strains shown in giving distinct primary lesions on the inoculated leaves as well as typical secondary symptoms. In each of these cases, the first leaf shows characteristic primary lesions and the second leaf the secondary symptoms. (Photograph by J. A. Carlile. From Cold Spring Harbor Symposia on Quantitative Biology.)

INDUSTRIAL DEVELOPMENT OF SYNTHETIC VITAMINS[1]

By Randolph T. Major
Merck & Co., Inc., Rahway, N. J.

[With 1 plate]

Much is written, both scientific and unscientific, in the papers and magazines of this country today about vitamins. In spite of this it might be well to define the word "vitamin" first. In the large unabridged dictionary in the writer's home, on the page where the word "vitamin" should be, may be found such words as "visitatorial," "vitaceae," "vitellarian," "vitelin," and "vitex"—but no word "vitamin." Later it was found listed in a separate place among new words. The front page of the dictionary shows that it was published in 1930. This observation gives some concept of the speed with which vitamins have become common knowledge.

As recently as 2 years ago, some people did not know the nature of vitamins. The purchasing agent of a large company which has a fine scientific laboratory visited us at that time. The discussion turned to vitamins. He said, "I am interested in vitamins, but I suppose no one has ever actually seen and handled a vitamin. Vitamins are something like electricity, aren't they?" He was taken into one of the laboratories and shown a bottle full of crystalline vitamin B_1. He was amazed.

For the purpose of this discussion vitamins might be defined as organic substances normally present in minute quantities in certain foodstuffs, the absence of which in the diet leads to well-defined morbid states.

The older so-called natural vitamins, vitamins A and D, will be mentioned very briefly. As you know, vitamins A and D, found in fish liver oils, are used in the treatment of rickets, especially in children and particularly during the winter, for the development of proper teeth, for the treatment of night-blindness, and for building up resistance to infection. Tablets and capsules of concentrates of

[1] Presented at a meeting of the American Section of the Society of Chemical Industry, March 27, 1942. Reprinted by permission from Chemical and Engineering News, vol. 20, April 25, 1942.

these vitamins in irradiated foods are available today. These vitamins have not been synthesized as yet, at least on a commercial scale. Certain individuals have claimed that they have synthesized concentrates of these vitamins, but they are not available generally.

Vitamin C, or ascorbic acid, was the first synthetic vitamin to be introduced commercially. It is used in the treatment and prevention of scurvy, some types of dental caries, and other disorders. It is available on the market in various pharmaceutical forms, and is put into beverages, confectionery, and certain special foods.

When interest was aroused in vitamin C a number of years ago, a little synthetic vitamin C was shown to a leading biochemist in an eastern university and he was asked, "What good do you think this will have?" His remarks, based upon his work in biochemistry over a good many years, were as follows:

> I think that it will find a place on the museum shelves of a number of universities, particularly of the biochemical departments. I think a few biochemists and a few pharmacologists will be interested in examining it. I do not think there will be any business in it. There is plenty of vitamin C available naturally in fruits, particularly in citrus fruits.

In contrast to this the United States Tariff Commission reports that in 1940 17 tons of vitamin C were produced synthetically in this country. From a reliable source comes the information that very shortly there will be 80 to 100 tons of vitamin C synthesized in this country annually.

In figure 1 is shown what happened to the price of vitamin C from the time natural ascorbic acid became commercially available in 1934 at something like $213 per ounce to the present when synthetic ascorbic acid may be had for $1.65 an ounce. Figure 1 also shows the tremendous drop in price when synthetic vitamin C first became available in 1937. Vitamin B_1 or thiamine is used in the prevention and treatment of beriberi, of lack of appetite in children, and of neuritis of various types. It is available in the various pharmaceutical forms, as well as in medicinal foods. Moreover, a new use for vitamin B_1 has developed which was not anticipated until recently. It is used in the enrichment of flour of which it is reliably stated that 40 percent of the flour used in our homes and 35 percent of the bakery flour used in this country is being enriched with vitamin B_1 today. Each pound of that flour must contain not less than 1.66 mg. of vitamin B_1.

Vitamin B_1 was not introduced into flour without encountering difficulties. One such difficulty is illustrated by the case of one of our good Jewish friends. When he heard that synthetic vitamin B_1 was being put in bread, he was greatly worried and inquired whether Jewish people might eat this bread. In other words, was it "kosher."

Fortunately for the enrichment program and also for our Jewish friends, it was determined to be kosher.

Some may wonder why an effort is being made to enrich white flour rather than to encourage more widespread use of whole wheat flour. That is too long a story to discuss here, but the following quotation from Oscar Wilde's "De Profundis" may prove interesting. In describing a man who had been in jail for some time, he wrote:

> Some six weeks ago I was allowed by the doctor to have white bread to eat instead of the coarse black or brown bread of ordinary prison fare. It is a great delicacy. It will sound strange that dry bread could possibly be a delicacy to anyone. To me it is so much so that at the close of each meal I carefully eat whatever crumbs may be left on my tin plate.

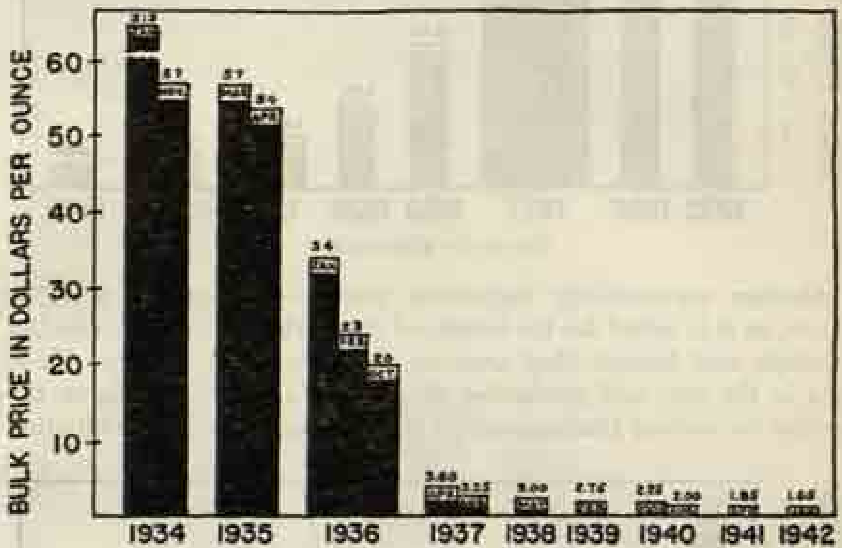


FIGURE 1.—Vitamin C.

The Army and Navy have specified that the bread baked for the soldiers and sailors must all be enriched. South Carolina has recently passed a law that requires the enrichment of all white flour used in the state.

Vitamin B_1 became available only in very recent years. Figure 2 illustrates the remarkable decrease in price that has occurred as the use of vitamin B_1 has grown. In 1935 when natural vitamin B_1 became available, it cost about \$300 per gram. In 1937 when the synthetic vitamin was first sold, the price dropped to \$7.50. The drop has continued until it is now being sold for \$0.53 per gram. It is reliably stated vitamin B_1 will soon be made in this country at the rate of 25 to 30 tons annually.

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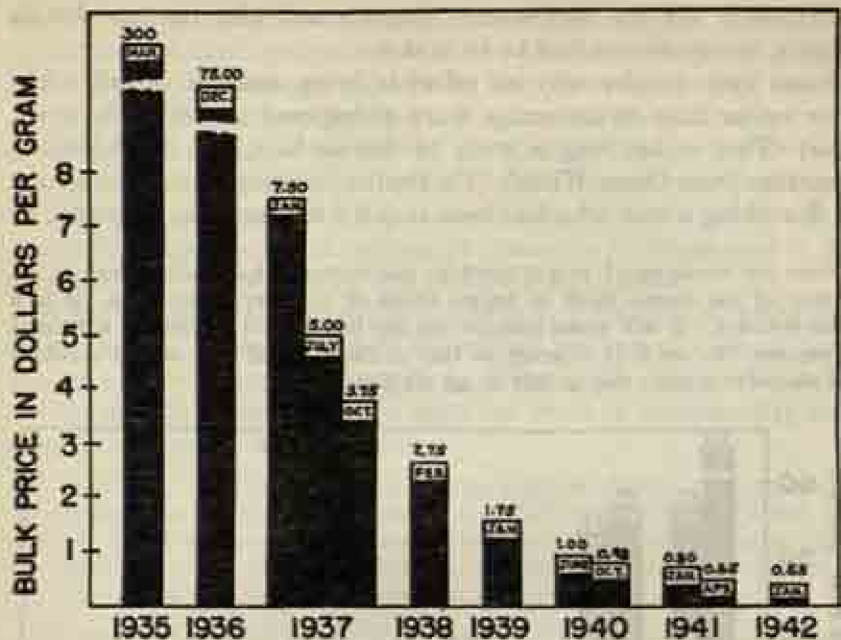


FIGURE 2.—Vitamin B_1.

Another commercially important vitamin is nicotinic acid, or niacin, as it is called for the benefit of those who object to consuming nicotinic acid because they associate the name with nicotine. It is used in the cure and prevention of pellagra and is available on the market in various pharmaceutical forms, sometimes in combination

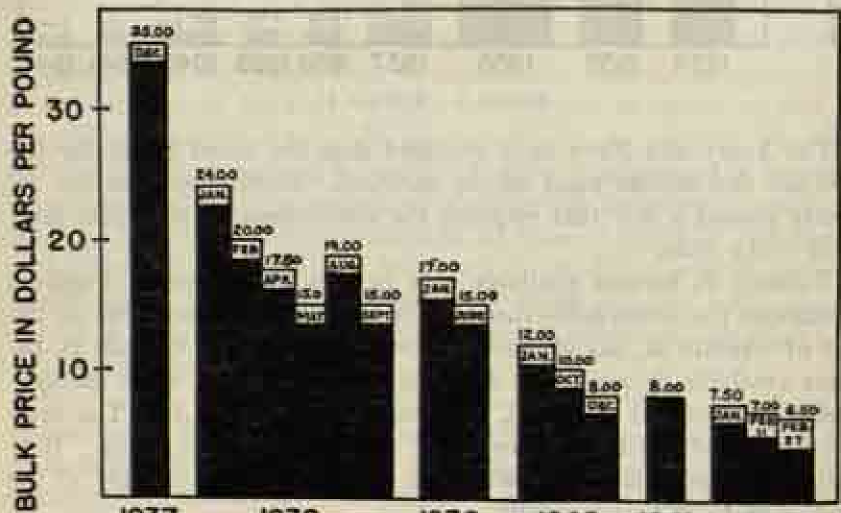


FIGURE 3.—Nicotinic acid.

with other vitamins and sometimes alone. It is available in medicinal foods and is added to all the enriched flour previously mentioned, in connection with vitamin B_1. Each pound of enriched flour must contain not less than 6 mg. of niacin.

The trend of the price of nicotinic acid since 1937 is shown in figure 3. The price of nicotinic acid in bulk has dropped from $35 per pound in 1937 to $6.50 per pound in February 1942. The decrease in price has not been so marked as in the case of some of the other vitamins, since nicotinic acid is an old, well-known compound. It is interesting, however, that increasing volume of production along with chemical and engineering studies has made it possible to decrease the price to the figure indicated, especially in times of generally rising prices.

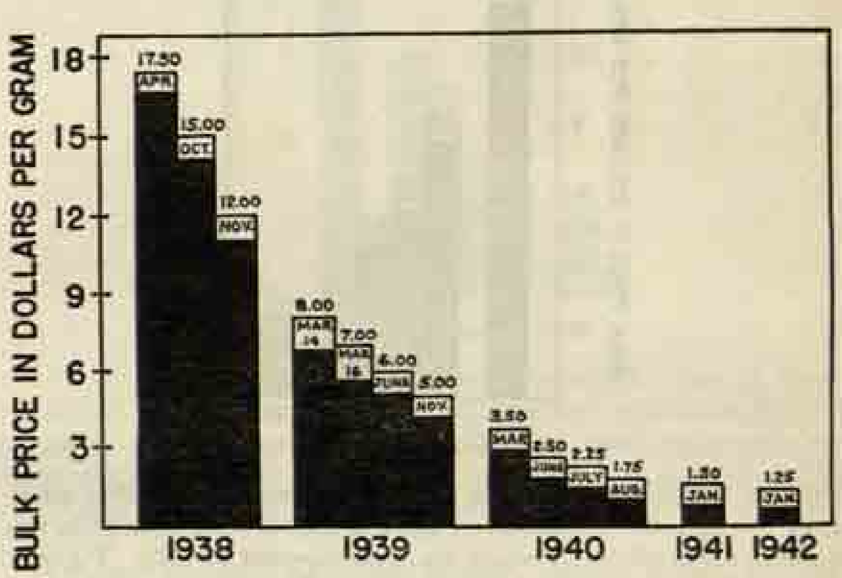


FIGURE 4.—Riboflavin.

Riboflavin (vitamin B_2) is used in the treatment of certain fissures of the lips and keratitis, a certain type of inflammation of the eyes, and also in the poultry industry to stimulate egg production. It is available in pharmaceutical preparations and in medicinal foods. Beginning July 1, 1942, it will be required in enriched flour if sufficient riboflavin is available then to enrich the enormous quantity of flour needed in this country. This requirement may have to be deferred for a few months because of a shortage of riboflavin owing to the difficulties that have been encountered in obtaining equipment necessary for its manufacture in sufficient quantity. For the enrichment of flour 1.2 mg. of riboflavin are required per pound of flour. The interest in riboflavin has also grown rapidly. In figure 4 is

presented the history of the bulk price of riboflavin, beginning in 1938 when synthetic riboflavin in bulk first became available at $17.50 per gram to the present time when it may be had for $1.25 per gram. This picture is not so striking as in the cases of vitamin C and vitamin B_1 since riboflavin has not yet been produced in as large quantities. Undoubtedly, however, the price of riboflavin will be lowered as production increases.

All the vitamins discussed in the preceding paragraphs have very definite, well-defined uses. The value of the next two vitamins to be discussed is not so well known. There are indications that the first of these, vitamin B_6, may be of value in the treatment of certain

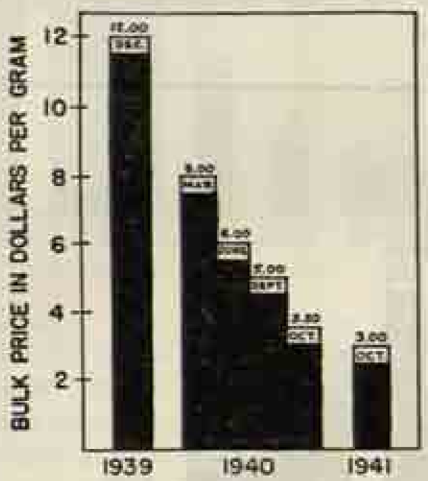


FIGURE 5.—Vitamin B_6.

muscular rigidities, in paralysis agitans, and perhaps for other conditions. In spite of this, however, there is considerable interest in this vitamin, the synthesis of which was first reported in 1939. Figure 5 presents the effect of increased production on its price since 1939.

As is the case with vitamin B_6, the biological and medical value of the next vitamin, calcium pantothenate, is poorly defined. However, everywhere one goes the value of pantothenic acid in the cure and prevention of white or gray hair is discussed.

In plate 1, figure 1, is shown a black rat whose fur has turned gray owing to a deficiency of pantothenic acid in its diet. Administration of pantothenic acid would change this fur back to its natural color. The Good Housekeeping Institute has published a statement that it is possible to change a human being's gray hair back to normal by the use of pantothenic acid. On the west coast calcium pantothenate is being added to a large proportion of the milk sold. Pantothenic acid in the form of its calcium salt is available in various pharmaceutical forms. In figure 6 is presented the change in price of calcium pan-

tothenate that has occurred with increasing use. Note that it was first made available just two years ago—in 1940.

There are a number of other vitamins that may be termed parts of the vitamin B complex. Among them are inositol which Dr. Woolley, of the Rockefeller Institute, observed has certain effects on the hair of mice, p-aminobenzoic acid which was proposed as a vitamin by another New Yorker, choline, and biotin. There are others, but they appear to be of still less importance, at least at this time.

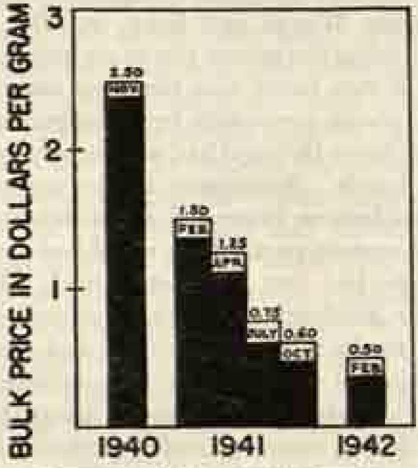


FIGURE 6.—Calcium pantothenate.

Two fat-soluble vitamins have been synthesized. One of these, vitamin K, is generally used in two forms—first as vitamin K_1, and second as 2-methylnaphthoquinone. Both of these compounds decrease the clotting time of the blood and are used in patients before operations, particularly in people suffering from jaundice, and also at childbirth.

The other synthetic fat-soluble vitamin, vitamin E, or α-tocopherol, is essential for proper reproduction in rats, but its value in human beings is quite uncertain. It may be of value in the correction of human sterility; and it may be important in the treatment of certain neuromuscular disorders.

DEVELOPMENT OF OUR KNOWLEDGE OF SYNTHETIC VITAMINS

Scurvy, a disease caused by lack of vitamin C, has been recognized for many, many years. It was a scourge to those who traveled long distances by boat until quite modern times. Many sailors and passengers on long voyages before the nineteenth century died of this disease before they reached their journey's end. But in 1804 the regular issue of a ration of lemon juice was made compulsory in the British Navy and thereafter scurvy was a comparatively rare disease among

British sailors. However, before vitamin C was isolated, the whole concept of some diseases being due to the lack of certain so-called accessory factors had to be recognized by scientists and much experimental work on animals performed. It was found that the guinea pig suffered from scurvy and was a suitable experimental animal for these studies. Using this animal as an indicator of activity it was possible by various methods of fractionation and separation to isolate crystalline vitamin C.

Vitamin C was isolated and first recognized as a vitamin by two American biochemists, Waugh and King, in 1932. After they had isolated vitamin C, using the guinea pig as an indicator of the activity of their fractions, it was found that the same material had been isolated from adrenal glands previously by a Hungarian, Szent-Györgyi, in 1928. However, Szent-Györgyi had not recognized that he had had vitamin C in his hands. Subsequent to the successful isolation of vitamin C, chemists became interested in its structure and synthesis. In 1933 chemists in various parts of the world had synthesized vitamin C after the structure had first been determined. One of these early syntheses is due to Reichstein, in which xylosone is converted to a nitril, hydrolyzed to the 2-keto sugar acid, and finally converted to ascorbic acid. This did not prove a very satisfactory commercial synthesis, because it started with xylose or lyxose, both of which are not readily available. A more successful synthesis, also due to Reichstein, used the readily available sugar, glucose, as raw material. Glucose was hydrogenated to sorbitol, converted to sorbose, then to diacetone sorbose, and then oxidized to 2-keto-*l*-gulonic acid which was converted into vitamin C. Among the other scientists who did considerable work on the synthesis of this vitamin are Karrer, Haworth, von Euler, and Micheel.

The first manufacture of natural vitamin C in this country took place in 1934. It was made from gladiolus leaves, which had been found to contain a relatively high percent of vitamin C. Fields of gladioli were planted in the vicinity of the author's company's factory. Many difficulties were encountered in collecting and extracting the plants on the day that they were cut.

Synthetic ascorbic acid was first made available in the United States in 1937.

Beriberi, the disease caused by the lack of vitamin B_1, was also recognized many years ago. Because so many people in the Orient have suffered from this disease, the attention of medical scientists was attracted to it at an early date. Most of the early work was carried on in the Orient. Takaki, the director-general of the Japanese Navy Medical Service, was able to banish beriberi from the Japanese Navy in 1882 by increasing the allowance of vegetables, fish, and meat in the navy diet and by using barley instead of polished rice. He recog-

nized that beriberi was caused by a badly balanced diet, but that is as far as his studies carried him.

In 1897, a Dutchman named Eijkman, working in Batavia, Java, found that beriberi resulted from continuous consumption of decorticated rice. He used the pigeon (pl. 1, fig. 2) as his test animal. In 1928, Jansen and Donath, working in the same laboratory as Eijkman, first isolated vitamin B_1 in minute quantities from rice polish. R. R. Williams, who started work some 30 years ago on the same problem in the Philippines, developed a practical method of isolating larger quantities of vitamin B_1 a few years later. However, it was soon obvious that large-scale equipment and chemical engineering skill would be required to produce the quantities of vitamin B_1 that were required to settle the structure of this vitamin. Dr. Williams turned to the author's laboratories for help on his problem. Larger quantities of vitamin B_1 were isolated and the structure of the vitamin was definitely established. Dr. Williams had previously carried out a crucial experiment, in which he had found that with sodium sulfite the vitamin could be split into two parts, a nitrogen-containing sulfonic acid and a sulfur-containing alcohol. In collaboration with Hans Clarke of Columbia University the latter was shown to be a thiazole derivative. After considerable additional work, the structure of the remaining fragment was determined by Dr. Williams and by Dr. Cline of our laboratory, and the synthesis was accomplished following an earlier synthesis of the thiazole moiety by Buchman and by Clarke and his associates. Independently the vitamin was synthesized by others, among them being Grewe, Andersag, and Westphal, and Todd and his associates. Two of these syntheses are graphically shown in figures 7 and 8.

A good many strictly technical difficulties have been encountered in the manufacture of vitamin B_1. The synthesis of the vitamin involves a good many reactions, some of which are very complex.

Other troubles were also encountered in its manufacture. One particular step, in days gone by, was especially affected by its accompanying odor. One man was finally moved to quit. When asked the reason, he claimed that his girl left him in the middle of the dance floor! His odor had overcome his charm! Many people leaving work would have a slight but definite odor of burnt rubber. One supervisor, on going to a movie, was somewhat embarrassed when the lady next to him rose and informed the manager that there was a short circuit or something burning near her. The manager, ushers, the lady, and others gave the area a careful inspection to find what was burning. However, the man was resourceful—he got down on his hands and knees and joined the search.

In 1915 Goldberger, a United States Public Health official, recognized that dietary deficiencies might play an important role in the

development of pellagra, a disease that was common in our southern States. It is reported that 400,000 to 500,000 people suffered from this disease every year. Investigations by Elvehjem led to his demonstration in 1937 that nicotinic acid would cure black tongue in dogs, a condition analogous to pellagra in man. Previous to 1937 nicotinic acid had been isolated from rice polish, liver, etc., but no one had recognized the significance of these findings. In 1938 Spies and his coworkers reported that nicotinic acid (niacin) was effective in the treatment of human pellagra, and its use naturally has spread rapidly.

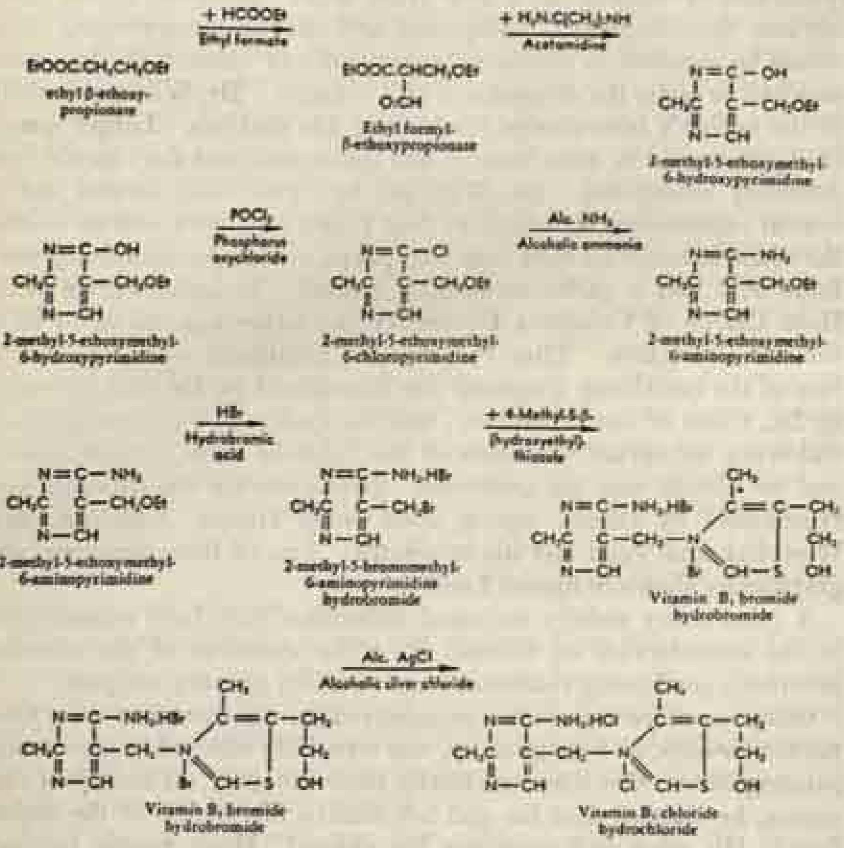


FIGURE 7.—Williams and associates synthesis of vitamin B_1.

Nicotinic acid was first prepared in 1867 by Huber by the oxidation of nicotine with potassium chromate and sulfuric acid. Later it was found that nitric acid could be used as the oxidizing agent. Nicotinic acid may be made also by other methods, such as the oxidation of quinoline or β-picoline or by the bromination of pyridine, followed by its conversion to the nitril of nicotinic acid and then by hydrolysis. Nicotinic acid is made in large quantities by processes such as these.

Early in the work on the vitamins, it was recognized that there were at least two water-soluble so-called B vitamins, one stable to heat and the other unstable. The latter was designated vitamin B_1, and the other, the heat-stable factor, was termed vitamin B_2. Later is was found there were several heat-stable factors, all essential for the growth of the rat. Using this animal in his tests, Kuhn and others showed in 1933 that one of the heat-stable factors, later termed riboflavin, was the same as a widely distributed and previously described yellow pigment in milk, liver, etc. He isolated the pigment from egg white and determined its structure. Both Kuhn and Karrer synthesized riboflavin in 1935. Karrer's synthesis is shown in figure 9. Other methods have been developed in this country for the synthesis of riboflavin.

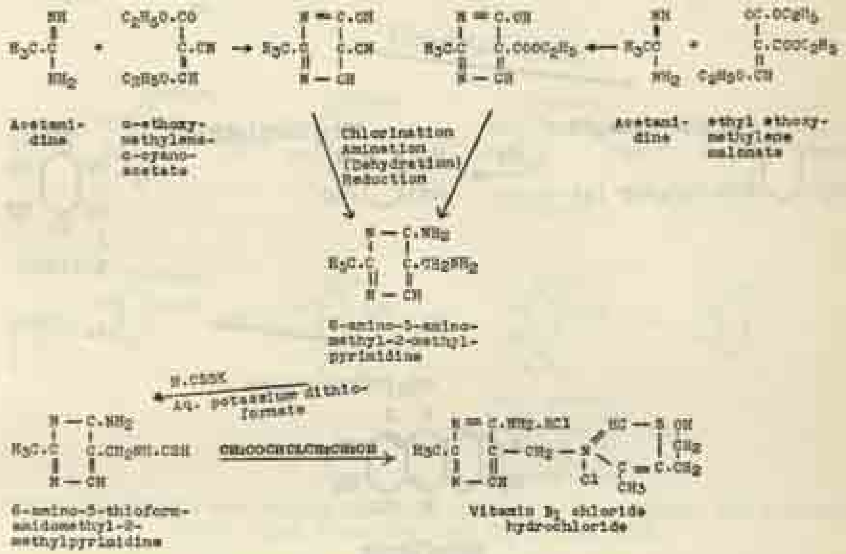


FIGURE 8.—Todd and Bergel synthesis of vitamin B_1. (Todd and Bergel, Journ. Chem. Soc. 1937, p. 364.)

Medical interest in this vitamin dates from the work of Sebrell and Butler in 1938 who found that it prevented and cured certain fissures in the corners of the mouths of human beings. Two years ago Sydenstricker found that it prevented and cured a certain type of keratitis. Recent examinations with the so-called slit lamp indicate that there may be a very widespread deficiency of riboflavin in the diet in this country.

In the manufacture of riboflavin the principal difficulty encountered has been the production of the ribose part of the molecule. Of course ribose is a very rare sugar. It has involved much work by night and by day, including Saturdays and Sundays, to find a good manufactur-

ing process for riboflavin. It is one thing to make such a compound in the laboratory when one is interested in making perhaps a gram or two of it, but quite another thing to do it on a large scale with reasonably good yields. The manufacture of these vitamins is carried out in typical manufacturing equipment, although it is not made on anywhere near the scale to which our friends in the heavy chemical industry are accustomed.

During the course of Goldberger's work on the pellagra-preventing factor, he was able to produce a syndrome in rats which was called rat pellagra when the rats were fed on diets deficient in this pellagra-

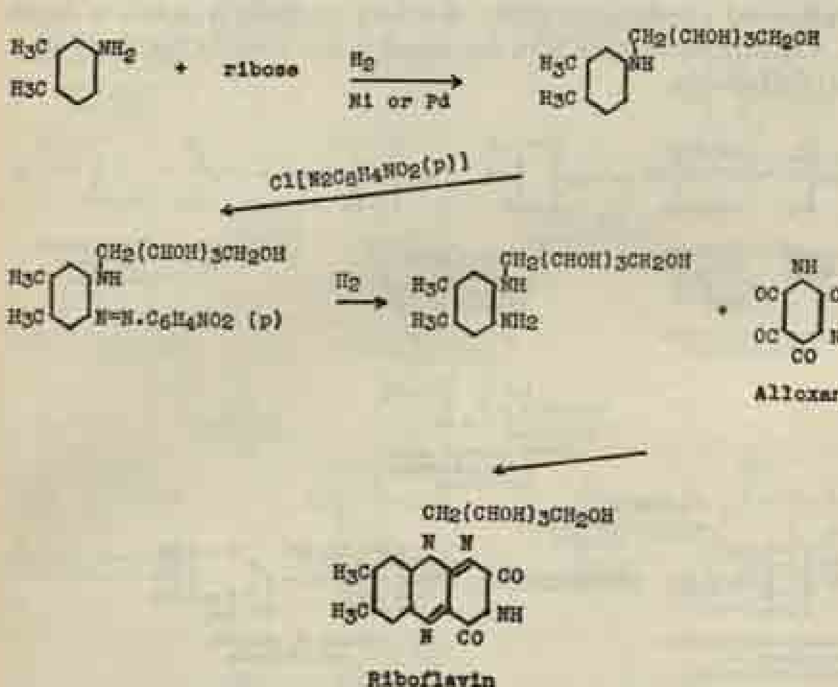


FIGURE 9.—Karrer and Meerwein synthesis of riboflavin. (Karrer and Meerwein, Helv. Chim. Acta, vol. 18, p. 1130, 1935.)

preventing factor. However, in 1935 György showed that rat pellagra was not caused by a deficiency of the pellagra-preventing factor but by a deficiency of a separate factor which he termed vitamin B_6, now known as pyridoxine. This compound was isolated by Drs. Keresztesy and Stevens in the Merck Laboratories and at about the same time in other laboratories by Lepkovsky, Kuhn, and Ichiba and Michi. Its synthesis was accomplished in the Merck Laboratories in 1939 by Drs. Harris and Folkers. As may be seen from figure 10, the synthesis is not simple, but in spite of this a number of good classical organic reactions have been used in its preparation.

In 1933 R. J. Williams discovered an acidic substance which occurred in many natural products that would stimulate the growth of yeast. In the meantime other workers had found that chicks bred under certain special dietary conditions developed a dermatitis which was attributed to the lack of a so-called filtrate factor. In 1939 Elvehjem and Lepkovsky and Jukes found that highly active concentrates of pantothenic acid would cure this chick dermatitis (pl. 1, fig. 3). Previously Williams had isolated a somewhat crude preparation of pantothenic acid from natural sources. He had shown that pantothenic acid was formed by the combination of β-alanine with a hydroxy acid. After

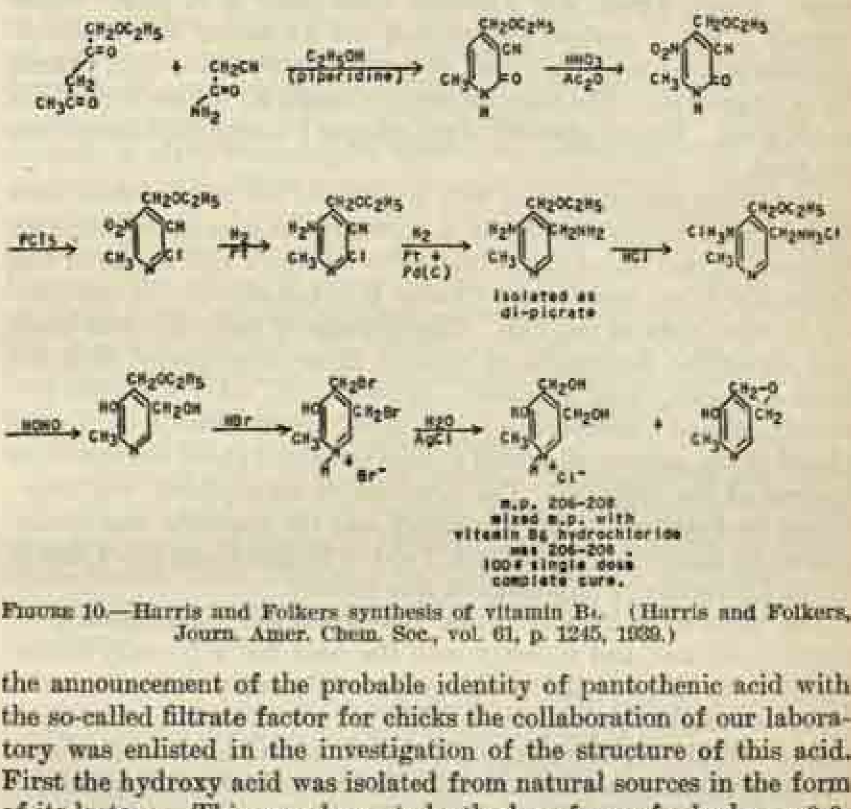


FIGURE 10.—Harris and Folkers synthesis of vitamin B6. (Harris and Folkers, Journ. Amer. Chem. Soc., vol. 61, p. 1245, 1939.)

the announcement of the probable identity of pantothenic acid with the so-called filtrate factor for chicks the collaboration of our laboratory was enlisted in the investigation of the structure of this acid. First the hydroxy acid was isolated from natural sources in the form of its lactone. This was shown to be the levo form of α-hydroxy-β,β-dimethyl-γ-butyrolactone. It was soon synthesized. Pantothenic acid was obtained by combining this lactone with salts of β-alanine or its ester followed by hydrolysis. Synthesis of pantothenic acid made it possible to establish without further question the identity of the chick "filtrate factor" with pantothenic acid.

As was mentioned previously, there has been a growing demand for calcium pantothenate and it is being manufactured in relatively large quantities.

In a study extending from 1929 to 1934 Dam and his associates described a deficiency disease of chicks which was characterized by a marked tendency to bleed. It was shown that the clotting time of the blood of chicks suffering from this disease was greatly prolonged. Dam found that hog liver contained a fat-soluble factor which would correct this condition. He termed it vitamin K. Subsequently Almquist obtained highly potent concentrates from alfalfa. Later Doisy and his associates succeeded in isolating what they termed vitamin K_1 in alfalfa and K_2 in fish meal. The structure of the more important of these, vitamin K_1, was found to be 2-methyl-3-phytylnaphthoqui none. Doisy, Fieser, and Almquist synthesized it in 1939. Subsequently it was announced by Fernholz and Ansbacher that 2-methylnaphthoquinone was as active as, or possibly more active than, vitamin K_1 or vitamin K_2. The manufacture of vitamin K_1 for use in medicine is not great. Larger amounts of the cheaper 2-methylnaphthoquinone are used.

In a study dating back to 1922 Evans and his collaborators have found that a dietary constituent is necessary for normal reproduction of rats. It was found that wheat germ oil was a rich source of this factor which has been termed vitamin E or tocopherol. It was present in other natural oils also. Concentrates of these oils were made and crystalline derivatives of vitamin E, or α-tocopherol as it has become known, were prepared. Subsequently other tocopherols—namely, β- and γ-tocopherols—were found which differ from α-tocopherol in the number of methyl groups contained about the chromane nucleus of the molecule. The structure of α-tocopherol was determined by Fernholz in our laboratory and the synthesis was accomplished by Karrer in Switzerland, Todd in England, and Lee I. Smith of the University of Minnesota in this country.

The importance of cooperation among academic laboratories, research institutes, and industry, and the need for a friendly understanding by each of the needs, goals, and problems of the others cannot be emphasized too much. The growth of modern industry is almost entirely dependent upon the great advances in pure science. Industry too has contributed much. It has made the findings of the pure scientist available to society. Discoveries in pure science are apt to become and remain sterile from the point of view of society unless industry makes use of them in some way. Examples of the great developments in industry based upon pure science are found in the great electrical industry which is so largely based upon the work of Faraday and other great pure scientists, or in the development of the dye industry which is based upon the work of the organic chemists of this country and abroad. This list could be increased almost ad infinitum.

Industry contributes to pure science by financially supporting research in universities and research institutes. It has made special chemicals, facilities for large-scale work, bioassays, and other expensive analyses and assays available to academic workers. It is very important that this work be continued, and it is very important too that it be continued to the mutual satisfaction of both the parties concerned. To attain this it is essential that the two groups understand what each is trying to achieve. The primary purposes of the academic institutions, of course, are the training of youth and the expansion and extension of man's mental horizons. These purposes are significant and important. The purpose and reason for the existence of the manufacturing industries are, of course, to manufacture and sell something that people want and need—in other words, to satisfy demands for some article or material. In doing this patents play an extremely important role. Patent protection on a new process or product is often necessary to obtain the money necessary for the equipment and facilities required to begin manufacture. Many writers state that the American patent system is responsible in no small measure for the remarkable development of American industry. However, the subject of patents is one on which the views of many acadamic investigators and industrial research investigators and business men differ widely. To achieve any real cooperation it is most important that both academic and industrial scientists achieve as thorough an understanding as possible of the purposes, benefits, and limitations of our American patent system.

In conclusion some general comments on the significance and social value of this food accessory business, the manufacture of synthetic vitamins, may be of interest. Through Claude R. Wickard, Secretary of the United States Department of Agriculture, the Government has issued a little pamphlet entitled "Food Will Win the War and Write the Peace." It states:

> Food is a whole arsenal of weapons in this struggle for human freedom. It is the driving force behind high production by munition workers, and top-notch performances and strong morale among soldiers and sailors.

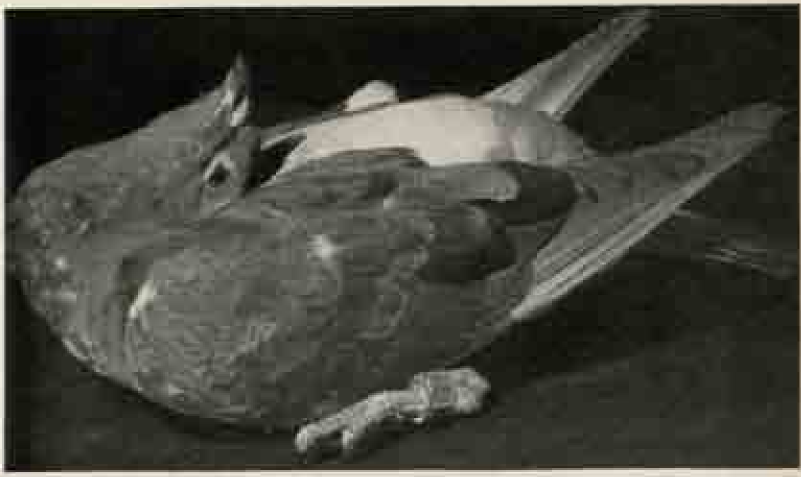
Somewhat in the same vein, Russell M. Wilder of the Mayo Clinic and former chairman of the committee on food and nutrition of the National Research Council has written:

> Famine has always contributed to defeat of armies and subjugation of nations. This has long been recognized, but in the past it was mistakenly thought that famine could be prevented if only the supply of food sufficed. The newer knowledge teaches that the nutritive quality of the foods supplied is of the utmost importance. . . . Caloric energy is needed, but no more than much else in food. . . . The new knowledge of nutrition has emphasized particularly the importance of what once were called accessory factors, namely salts and vitamins. . . . Vitamin deficiencies constitute the principal "hidden hungers," subclinical abnormalities which until lately, for the most part, were unrecognized.

This new industry in synthetic vitamins is making it possible to satisfy many of these "hidden hungers" and to improve the nutrition and well-being of our people.

In comparing the contributions of the nutrition workers of the twentieth century with those of earlier workers in the nineteenth century, such as Pasteur and Lister, from whose work came a recognition of the bacterial origin of disease, we may conclude that the social value of the present work in nutrition would appear to be as significant as that of the nineteenth-century investigators to whom mankind owes so much.

1. GRAY HAIR OF BLACK RAT DUE TO PANTOTHENIC ACID DEFICIENT DIET.



2. POLYNEURITIS OF PIGEON DUE TO A VITAMIN B_1 DEFICIENT DIET.

3. DERMATITIS OF CHICK DUE TO PANTOTHENIC ACID DEFICIENT DIET.

THE NUTRITIONAL REQUIREMENTS OF MAN[1]

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Department of Biochemistry
University of Wisconsin

At the present time the nutritional requirements of man can be expressed in chemical terms to a greater extent than ever before. However, we as chemists must recognize that there is more to adequate nutrition than the mere combining of the known compounds into a diet and the calculation of the cost of these dietary constituents. Owing to the fact that some of the vitamins that were formerly the costly part of our diet may now be purchased at prices so low that they are difficult for us to comprehend, certain erroneous suggestions have been made concerning the cost of an average diet. It is true that one's yearly requirement of thiamin may now be purchased for about 50 cents and the nicotinic acid supply for about 12 cents at wholesale prices. But we must not forget that the yearly supply of calories is still a significant item in our diet. Most of us ignore calories until times of stress. Even in the last war one of the greatest problems in many countries was an adequate supply of total food. If my calculations are correct I find that it would be difficult to supply one's yearly requirement for energy for much less than $15, and the cost of adequate protein would certainly exceed this value. Thus if we add up the cost of the individual components we get values considerably higher than some of the figures which have recently been suggested by certain workers. It is impossible even to estimate the cost of the unknown factors.

I believe the safest program at this time is to rely upon the common foods which we have been accustomed to eating rather than attempting the production of cheap, synthetic substitutes. However, we should make every effort to improve the quality of the foods that are now making up the American dietary. In other words, we

[1] Given before Symposium on Nutritional Restoration and Fortification of Foods, Division of Agricultural and Food Chemistry and Biological Chemistry, American Chemical Society Meeting, St. Louis, Mo., April 8, 1941. Reprinted by permission from Industrial and Engineering Chemistry, vol. 33, June 1941.

must realize that plant and animal products as produced on the surface of this earth do not necessarily contain the individual nutrients in optimum concentration for the human being. We must use some ingenuity in compounding natural food materials into a complete diet. Improvement in the quality of certain food supplies will not only conserve total quantity of food but will tend toward more optimum nutrition of all indviduals.

Our problem today centers around the restoration and fortification of foods. I should like to mention in passing that the interest in this problem is undoubtedly stimulated by our national defense program, but we should also recognize that we have reached a stage in our knowledge of nutrition which makes it possible for us to consider this problem. At first nutrition workers recognized that certain foods were excellent sources of specific nutrients. These foods became known as protective foods and we relied on these specific foods to a considerable extent for our supply of essential factors. When we recognized that inorganic salts were utilized as readily by the body as the mineral elements found in our natural foods and that synthetic vitamins could be produced at a fairly low cost, considerable interest was shown in the use of concentrates or capsules to supply some of the more important nutrients. The value of these preparations in the clinical treatment of deficiency diseases cannot be denied, but we must recognize that the administration of such concentrated forms of nutrients should be only temporary in nature. If large groups of people are living on combinations of natural foods which do not supply the total requirement, the food supply should be modified or fortified.

As the chemists showed greater interest in these problems, methods of assay have improved so that we can analyze our staple foods for their vitamin content. These foods are not devoid of vitamins, as many would have us believe, but show a low content on the percentage basis. If we multiply the amount present by the total weight of the food consumed daily we find that the result may be an appreciable part of the entire requirement. I am sure that in the future we will look back upon this work as one of the most important periods in nutritional research.

It is obvious that values for the distribution of nutrients in foods are not of much use until we know the requirement for each of these nutrients. If we had all these values available it would not be very difficult for the dietitian to handle the food supply so as to give us adequate nutrition through the use of pleasing foods.

The establishment of nutritional requirements has also had a rather interesting history. In a few cases the actual requirement has been studied on human beings. Thus we have a considerable number of data for the energy requirement of human beings of different ages.

The data on the protein requirement are somewhat limited, although there is today fairly general agreement among many workers as to this constituent of our diet. There have also been a few studies on the requirements for calcium, phosphorus, and iron. In the case of many of the vitamins, the data have been obtained through animal experiments and generally from work that was not initiated to answer this particular question. I am afraid that many of us have been guilty of concluding from our animal experiments that a vitamin is needed at a certain level and then for good measure we suggest that the daily human requirement would be 50 percent greater than the value found.

This method may be quite satisfactory in order to establish a certain degree of safety. However, if we were to do this in all our calculations, I am afraid we would soon pile up a considerable excess. For example, if we were making an automobile trip of 200 miles each day and our car required one gallon of gas for 20 miles, the first day we would then need 10 gallons, but for safety's sake we would put in 15. If we did that each day we would soon find that our gasoline tank was overflowing.

The following figures may be used as a guide for the daily requirement of the better-known nutrients. These values will, of course, vary depending upon the age of the individual and whether there are certain increased requirements superimposed upon the ordinary requirements. These problems are largely physiological and I will not go into them here. The figures given in table 1 are those recognized for the average male adult. I should like to discuss very briefly how these values have been obtained, their limitations, and how the chemist can aid in establishing more satisfactory values.

TABLE 1.—*A guide for the daily requirement of the better-known nutrients*

Protein	70 grams.
Calcium	0.7 grams.
Iron	12 mg.
Vitamin A	4,000–5,000 I. U.
Vitamin B_1	1.5–2.0 mg.
Vitamin C	50–75 mg.
Riboflavin	2–3 mg.
Nicotinic acid	10–15 mg.
Vitamin D	400 I. U.

It is, perhaps, unnecessary to say much about the energy or the protein requirements. In spite of the extensive values for the caloric requirements of human beings under different conditions, little attention has been given to the effect of the external environment on the caloric intake. Mills and Calvin (1) have recently shown that excessive external temperatures may reduce the intake

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of calories to the point that sufficient food is not consumed to supply the normal vitamin requirement. We still speak of the protein requirement in total grams of protein in the diet, while actually it is not the protein requirement that we are interested in, but the amino acid requirement. Some day we may be able to state the actual amino acid requirements and obtain values for the amino acid content of all our food supplies. At present this may seem very difficult, but the analysis of food materials for vitamins A, B_1, and C also appeared very difficult a few years ago. The value of 70 grams of protein per day for an adult man is probably a safe figure provided we specify that the protein should be derived from a variety of sources and a good part of it from animal tissues.

No definite figures have been established for the fat content of human dietaries. It is generally concluded that fat must be a constituent of the normal diet and that it is well to use liberal amounts to supply the fat-soluble vitamins. The latter suggestion is not absolutely essential since we can now get concentrates of these vitamins; however, the importance of fat as a source of linoleic acid must be considered. There is no question about the production of linoleic acid deficiency in rats on fat-low diets but few studies have been made with other species. There is some difference of opinion concerning the importance of linoleic acid in the human dietary. A high intake of linoleic acid containing fats has been used in the treatment of eczema; and Brown, Hansen, Burr, and McQuarrie (2) found a decrease in the amount of linoleic acid and arachidonic acid in the serum of an adult man subsisting for 6 months on a diet extremely low in fat. The individual exhibited no other evidence of disease. We have found in our laboratory that rats maintained on mineralized skim milk fortified with minerals and the fat-soluble vitamins grow better when the skim milk is supplemented with butter fat than when vegetable oils are used. The active substance is present in the fatty acid fraction of the butter fat.

It is also well known that fat has a sparing effect on vitamin B_1. The general decrease in the fat content of American dietaries has thus tended to aggravate the vitamin B_1 deficiency brought about by the use of refined foods.

Calcium logically heads the list of mineral elements of significance in nutrition since there is more calcium in the human body than any other mineral element. The value generally accepted today as an adequate level is 0.7 to 0.8 gm. per day. We must first recognize that this calcium requirement holds only when the diet contains an adequate supply of vitamin D. The Ca:P ratio is also a factor that needs definite consideration. We still find in certain textbooks that the optimum Ca:P ratio is 2:1. This is obviously incorrect since in all of our work we have found the ratio to approach 1.2:1.

Experiments with dogs indicate that when the Ca:P ratio is 2:1, it is impossible to get normal calcification even with tremendous doses of vitamin D. Sherman and coworkers (3) have recently reported some improvement in the nutritional well-being of rats by increasing the calcium intake from 0.2 percent to 0.35 percent or even to 0.8 percent of the diet. The phosphorus requirement is generally assumed to be a little higher than the calcium figures. This may appear contradictory in the light of a calcium phosphorus ratio of 1.2 to 1; however, the higher value may be advantageous because some of the organic phosphorus may not be completely available. The phosphorus in phytic acid is now known (4) to be available, but it is less efficient for bone production than other sources of phosphorus.

The daily iron requirement is rather well established although the exact figure has varied between 12 and 15 mg. per day. First we must recognize that the iron is of no value in the body unless it is accompanied by copper which functions in the conversion of iron into hemoglobin. In addition the iron must be in an available form. Extensive studies have been made on the available iron content of foods, and the values obtained by chemical methods check fairly well with those obtained through the feeding experiments with rats. However, we still do not know whether the availability as measured in rats is similar to that which we may find in the human being. Much has been said about the relative value of ferric and ferrous iron. This problem has recently been thoroughly studied by Tompsett (5). Ferrous iron appears to be the only form to be absorbed from the alimentary tract. The ferric iron consumed is reduced in the stomach and this reduction is brought about by substances which are common constituents of the diet. The diet may also contain substances which tend to oxidize the ferrous iron to the ferric state. The phosphatides of egg yolk appear to be one group of substances which inhibit the absorption of iron through the autoxidation of the ferrous iron. Tompsett states that it is difficult to give a definite value for iron because the degree of iron absorption is dependent on so many factors. The value of 12–15 mg. per day is probably liberal enough to compensate for the iron present in the food in forms that cannot be utilized. The daily copper requirement is probably about 2 mg. per day and practically all forms of copper show equal availability.

No requirements have been set up for the remaining so-called trace elements and perhaps rightly so, since we have no specific values available. But we must recognize that elements such as manganese, zinc, and cobalt are important in the diet, and perhaps values for these additional minerals may soon be available.

Most of the work on iodine requirements has been done directly on human beings. One reason for this is undoubtedly due to the fact that it is difficult to produce an iodine deficiency in experimental animals although many farm animals in the goiter region suffer from iodine deficiency. Balance studies (6) show that 50 to 100 micrograms of iodine per day may be sufficient. The value generally given is 2 micrograms per kilogram of body weight. There is ample evidence that these small requirements may not be met by foods and drinking water. In order to meet this difficulty the fortification of salt was started in this country over 15 years ago. This was the first fortification program in this country. Sufficient NaI or KI is added to maintain the iodine content of salt at 0.015 percent.

Turning then to a discussion of the vitamins we find even more conflicting data. The main difficulty encountered is that there are several different chemical compounds which may have similar physiological effects. Yet the quantitative activity of these different compounds varies to a considerable extent. In the case of vitamin A our foods contain both the classical vitamin A and carotene, as well as other related carotenoids. A value of 5,000 I. U. has been suggested on the basis that the average diet supplies one-third of the total activity in the form of vitamin A and two-thirds in the form of carotene. Two thousand I. U. of vitamin A as such will undoubtedly meet the daily needs. Some day it may be advisable to set specific standards for the carotene requirement and the vitamin A requirement and to express the distribution of both these compounds in our food materials. The absorption of vitamin A from the intestinal tract is definitely related to the fat content of our diet and the actual requirement may differ drastically depending upon the presence of other materials in the diet.

The vitamin D requirement, as I have mentioned, is dependent upon the total calcium and phosphorus intake as well as the calcium and phosphorus ratio and may differ considerably depending upon whether the diet contains ample quantities of milk or whether the diet is low in this food. Apparently the different forms of vitamin D do not vary sufficiently to make this a problem in human studies. I believe we are safe in accepting a value of 400 I. U. per day.

No requirements have been stated for vitamins K or E because so little information is available. Under normal conditions there is sufficient synthesis of vitamin K in the intestinal tract to meet the requirement. However, any change in the intestinal flora might bring about a definite increase in the need for preformed vitamin K in the diet.

The vitamin C requirement is rather definitely established because the chemist has been able to determine this factor rather simply not only in foods but also in the blood stream. Several groups of workers

have shown that 70 mg. per day will maintain the vitamin C content of the blood at high levels. The important question in this case is whether we should supply sufficient vitamin C to produce complete saturation of the blood stream, or whether optimum health can be maintained at lower levels of saturation.

At the present time there appears to be greater interest in the vitamin B_1 requirement than any of the other vitamins. This is perhaps due to the fact that it is practically impossible to study the vitamin B_1 content of the blood and we must resort largely to balance studies. Many of the balance studies have been conducted for short periods of time, and such studies may give results considerably higher than those obtained over a long period of time. Another factor which perhaps enters into this problem is the fact that the vitamin B_1 requirement is definitely reduced by a high fat diet. Recent studies at the Banting Institute have suggested that high-fat diets may eliminate all symptoms of B_1 deficiency except those changes taking place in the heart. If this is true, we should perhaps recommend the high level of B_1 intake regardless of what the fat content of the diet is. A level of 1.5 to 2 mg. per day should supply an adequate intake for most individuals. In studies conducted by Williams, Mason, Wilder and Smith (7) it was found that about 1 mg. prevented symptoms but higher levels gave a high degree of well-being.

The very recent work on human beings (8) seems to establish rather definitely that the riboflavin content is 3 mg. per day. These studies were conducted on human beings receiving average diets, but again, changing the fat and carbohydrate ratio may alter the riboflavin requirement. We have recently shown in our laboratory that when the fat content of the diet is increased we find a considerable increase in the riboflavin requirement. This we interpret in a preliminary way as being caused by a change in the bacterial flora. That is, under normal conditions there may be a certain degree of riboflavin synthesis in the intestinal tract and we are merely measuring the riboflavin required above this synthesis. If there are sudden changes in the intestinal flora, the entire riboflavin requirement may have to be supplied through the diet.

It would appear that the nicotinic acid requirement might be established very easily since nicotinic acid is such a simple chemical compound. Tremendous difficulties have been encountered in attempting to determine the nicotinic acid content of foods or to measure the nicotinic acid excreted in the urine. Two recent developments, I believe, will be of considerable value in establishing the nicotinic acid requirement. One is that we are now able to feed dogs on a highly synthetic diet containing no nicotinic acid and from these studies it would appear that the daily requirement for maintenance is about 0.25 mg. per kilo and the requirement for growth

is about 0.5 mg. per kilo. Using these values then, it would appear that the nicotinic acid requirement of a human being is at least 15 mg. per day. Bacteriological methods have also recently been developed for nicotinic acid determination and these procedures give accurate results. By calculating the nicotinic acid content of an average diet it would appear that it contains 15 to 20 mg. per daily portion. As far as we know, there are no factors in the average diet which tend to alter the nicotinic acid requirement, although increased exercise may have a definite effect on the requirement of this factor.

The greatest limitation in the above figures is the lack of recognition of the less-known vitamins. Certainly the vitamin B_6 requirement of a human being may be as important as any of the other B vitamins. Yet we have no way of setting a specific figure at the present time. We can only make a rough assumption that the vitamin B_6 requirement is in the same order of magnitude as vitamin B_1.

Pantothenic acid is undoubtedly required by the human being, but at the present time we cannot even give quantitative figures for the requirement of pantothenic acid in animals. Again the pantothenic acid apparently affects the requirement of some of the unknown members of the B complex in the animal; whether pantothenic acid has a similar effect in human beings needs further study.

Another factor which has received a great deal of attention in animal work during the past year or two is choline. The serious difficulties that an animal encounters when diets low in choline are used certainly suggest that studies on the importance of choline in the human dietary should be made. Here again we have an example of how the variation in the amino acid content of our diet may affect the choline requirement since a high methionine intake tends to decrease the choline requirement and a high cystine intake tends to increase the choline requirement.

We must, of course, recognize that much of our information regarding the human requirements has come from animal experiments. In fact if we had not relied upon animal work we would not have much information at the present time. But if we use the results from animals we must realize that there is great variation in the requirements of different species. This was first recognized, of course, in the case of vitamin C when rats failed to require vitamin C while the human being, monkey, and guinea pig did. We are finding more and more such discrepancies. The most interesting perhaps is the variation in the nicotinic acid requirement in different species. The rat and chicken apparently do not need this factor preformed, while the dog is very sensitive to a lack of this factor. Apparently the human being and the dog are very similar in their requirements for nicotinic acid. We are now finding that

the ruminant can get along on diets practically devoid of the vitamin B complex because all these factors are synthesized by the bacteria in the rumen. Recent work indicates that the rat can synthesize some of the unknown members of the B complex and that high levels of pantothenic acid apparently favor this synthesis.

If we turn to the guinea pig we find quite different results than those obtained with other animals. A young guinea pig fails to grow normally and dies in a few weeks when fed purified diets upon which rats and dogs may grow very well. We have found that these animals will grow if we supplement the purified diet with dried grass, yeast, and fresh milk. Chicks also require additional amino acids and certain factors from yeast before they will develop normally on synthetic diets. How these facts relate to human nutrition is not known, but these results do suggest the importance of additional work. These problems require all the ingenuity that chemists can contribute.

In conclusion then, we may agree that the nutritional requirements of man can be expressed in quantitative terms to a very extensive degree. These values are of great importance in constructing adequate diets provided we still obtain a considerable proportion of the nutrient from natural foods. The safest program for the future involves the improvement of natural and processed foods through restoration and fortification. Thus recent criticisms leveled at the fortification program are invalid because we are not adding enriched foods to synthetic diets but to diets that are already fairly adequate. The fortification of foods like bread merely brings the diet from a borderline state of adequacy to an optimum and efficient state. We may not have all the knowledge for optimum fortification but as long as the use of natural foods is continued, the danger of imbalance is greatly reduced.

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PAST AND PRESENT STATUS OF THE MARINE MAMMALS OF SOUTH AMERICA AND THE WEST INDIES[1]

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Changes in the shore lines of the South American continent, resulting from the submergence and subsequent elevation of areas of varying extent at different times during that portion of the geologic past known as the Tertiary period, provide a succession of sedimentary formations from which have come an essential part of the factual evidence employed by paleontologists in reconstructing the history of the mammals during this period of the earth's history. Some of these sedimentary strata, when examined critically, are found to be ancient beaches, estuaries, and river deltas, and, what is more important, to contain bones belonging to extinct types of marine mammals. By means of these fossil remains the genealogical history of some of these marine mammals can be traced with some degree of accuracy from the time they make their appearance down to the present.

The history of the sea cows or sirenians in the Western Hemisphere begins with a sirenian (*Prorastomus sirenoides*) of uncertain relationships, probably as old geologically as any of the known Middle Eocene sirenians of Africa and Europe, which was found prior to 1855 in a calcareous sandstone nodule in the bed of a Jamaican River. During the succeeding interval of geologic time, the Oligocene, a later type of sea cow (*Halitherium*) frequented the Caribbean Sea, the remains of one individual having been found in Puerto Rico.

No cetaceans of Oligocene age are known to occur either in the West Indies or in South America. A rather varied assemblage does make its appearance, however, in the Lower Miocene Patagonian marine formation of Argentina. This formation has yielded two distinct kinds of shark-toothed porpoises, a ziphioid beaked whale, a rather dubious relative of the iniid river porpoises, a long-snouted

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porpoise unlike any living member of this group, two different kinds of sperm whales, and three kinds of whalebone whales. One of these whalebone whales (*Morenocetus parvus*) is the oldest geologically of all known members of the family of right whales (Balaenidae). The other two represent cetotheres, the precursors of the living furrow-throated whalebone whales.

Members of the family of river porpoises (Iniidae) ranged northward in the Atlantic Ocean to Chesapeake Bay and in the Pacific Ocean to San Francisco Bay during the Miocene. The late Miocene or early Pliocene Piso Entreriano exposed along the river banks in the vicinity of Paraná, Argentina, has furnished at least five kinds of extinct iniid river porpoises. From these were derived a number of succeeding types. In the course of geologic time most of these types of ancient iniid porpoises disappeared, leaving only two survivors, the white flag porpoise in Tung Ting Lake, Hunan Province, China, and the bouto in the Amazon and its tributaries.

Evidence is still lacking in regard to the main details of the developmental history of the pinnipeds. Nevertheless, it is now certain that at least one relative of the Recent hair seals (*Prionodelphis rovereti*) was included in this late Miocene or early Pliocene fauna.

Remains of whalebone whales have been found in rocks of Pliocene age near Coquimbo, Chile, and also on the plains east of the port of Lomas, Peru.

Ear bones and other miscellaneous skeletal elements representing one or more kinds of extinct whalebone whales have been found in the Pleistocene Pampean formation of Argentina. In contemporary deposits at Olivos in the Province of Buenos Aires, Argentina, a relative of the southern sea lion was obtained. In the more recent deposits of Argentina, bones representing a close relative of this sea lion seem to occur more frequently.

SEALING IN THE SOUTHERN HEMISPHERE

We now come to the period when man by his interference radically changed the original aspect of the existing marine fauna. We are so overwhelmed today with problems associated with the marketing of ever-increasing surpluses of cereals and livestock products that few of us appreciate the situation confronting early colonists in the New World. Fats and oils were in constant demand and the colonists were obliged to utilize all available resources. Consequently, bison were slaughtered for tallow, while oil suitable for burning in lamps was readily obtained from seals, porpoises, and whales. Unproductive soil, the absence of remunerative employment in the vicinity of the settlements, and the increasing demand for oils and fats made sealing and whaling an attractive occupation for residents of

many coast villages. The reckless manner in which these marine resources were exploited, however, can hardly be witnessed again since these animals no longer exist in considerable numbers in most of the oceanic areas where they were slaughtered during the past three centuries.

WEST INDIAN SEAL

One of the first animals in the New World to bear the brunt of man's destructive proclivities was the West Indian seal (*Monachus tropicalis*). It is recorded that Columbus (Kerr, 1811, vol. 3, pp. 124, 327) toward the end of August 1494, while cruising among the West Indian islands in search of a passage to the mythical province of Cipango, lost sight of the other vessels of his flotilla, and anchored off the south coast of Haiti. Sailors were sent to climb the rocky islet of Alta Vela and to scan the horizon for the missing vessels. On descending from these rocks the sailors came on a number of seals asleep on the sands and killed eight of them. In such a manner, the seals of the New World became acquainted with the civilized white race.

Spaniards from Yucatán and Englishmen from Jamaica before 1675 (Dampier, 1705, vol. 2, pt. 2, pp. 26–27) sailed to the Scorpion Islands north of Yucatán for the express purpose of killing these seals for their oil. Sir Hans Sloane, who visited the Bahamas in 1687–88, was told that West Indian seals were so numerous on those islands that fishermen took as many as a hundred in one night. By 1843, however, this seal seems to have been restricted to the Pedro Keys off the south coast of Jamaica (Lucas, 1891, p. 616), to the Anina Islands lying between the Isle of Pines and Yucatán (J. A. Allen, 1880, p. 721), and off the northern coast of Yucatán to the low sand spits surrounded by coral reefs known as the Triangle Keys. Large numbers of these seals were killed on Triangle Keys before 1856 (Lucas, 1891, p. 616). As late as 1900, however, a small colony of not over 75 was found by E. A. Goldman to exist on these keys. The present status of the West Indian seal is unknown.

SOUTHERN SEA LION

Seals in the Southern Hemisphere, however, were not accounted an article of commerce until the leading seafaring nations of the world began the active exploration of the coasts of South America. It was not until these early navigators had sailed southward along the coast beyond the present boundaries of Brazil that the southern sea lions (*Otaria flavescens*) were discovered. These animals congregate during the southern summer on their breeding grounds which are located along the coasts of South America mostly south of the La Plata River on the Atlantic side and as far north as northern Peru on the Pacific side, as well as on the Falkland and Galápagos Islands.

Magellan in October 1520 recorded their presence in the Magellan Straits. Subsequent navigators were accustomed to provision their vessels with sea lion meat and to replenish their oil supply from the blubber of this large seal. The expedition led by Simón de Alcazaba, for instance, in 1535 took two or three hundred sea lions on an island off the coast of Chubut, Patagonia. Similarly, Sir Francis Drake in 1577 provisioned his vessels with some 200 sea lions killed at Port Desire, Patagonia.

Although sailors on subsequent voyages frequently salted hogsheads of sea lion meat for provisions, it was not until late in the eighteenth century that the traffic in sea lion skins assumed any marked proportions. Accurate figures of the catch during these years are, however, not available. Nevertheless, some idea of the extent of the trade in these skins may be gained from the fact that at least 52,000 sea lion skins were taken in 1821-22 by the shore crews of the American brigs *Alabama* and *Frederick* on the islands of Mocha and St. Marys off the coast of Chile (Balch, 1909, p. 484).

Not even the colonies on the Galápagos Islands escaped from the general slaughter. In 1815–16, the crew of the ship *Volunteer* of New York loaded the skins of 2,000 sea lions and 8,000 fur seals that had been killed on these islands by the ship's shore crew (Fanning, 1924, pp. 287–288). The hides of sea lions were used by the harness and trunk makers of New England. The demand for these hides, however, was not so great as to cause the near extermination of the southern sea lion.

Sealers are still taking sea lions on the South Falkland Islands, but in accordance with regulations provided by a license system. The take on these islands in 1930 amounted to 4,563 sea lions (Hamilton, 1934, p. 313). Two companies licensed by the Peruvian Government are reported to take from 75,000 to 80,000 sea lion skins annually from the rookeries located along the coast of Peru.

SOUTHERN ELEPHANT SEAL

At the end of the eighteenth century, elephant seals were present in countless thousands on many of the islands off the southern extremity of South America, particularly along the Patagonian coast, Tierra del Fuego and southern Chile, as well as on Juan Fernández, the Falkland Islands, the Southern Shetland and South Orkney Islands, and South Georgia.

The records show that as early as 1774 vessels from New York and Nantucket were outfitted not only for whaling but also for sealing on the South Falklands. The abundance of elephant seals and the current demand for oil led almost at once to the indiscriminate slaughter of these huge seals. By 1800, the southern elephant seal fishery had reached considerable proportions. Gangs of men with

limited provisions and huge 250-gallon trying pots were put ashore in shallops at accessible beaches from sealing vessels anchored in safe harbors. Partial and sometimes full cargoes of elephant seal oil were shipped to ports in the Old and the New Worlds.

From 1799 to 1818, sealing vessels from Nantucket and New Bedford were bringing back elephant seal oil from Patagonia and Staten Island. Similarly, many vessels sailed from New London, Conn., for the Falkland Islands and South Georgia.

The absence of accurate records of the catch made by vessels engaged in this business makes it impossible to estimate the number of elephant seals killed on southern rookeries. Some sealers held that an average of 3 barrels (94.5 gallons) of oil was obtained from an adult elephant seal, but both young and adults were killed. The cargo of 1,500 barrels of oil brought back to Stonington, Conn., by the schooner *Free Gift* in April 1822 represented a kill of at least 500 elephant seals, assuming that all were adults. Weddell in 1823 recorded that 20,000 tons of elephant seal oil, representing the death of at least 62,000 animals, had been shipped to London alone from South Georgia.

So oblivious were these elephant seals to the killing that was going on around them and so indiscriminately were the young and old slaughtered, that in a comparatively few years they were exterminated or reduced to a mere remnant along all the coasts and on the islands that had once been their refuge. Elephant seals disappeared successively from the Falklands, Juan Fernández, South Shetlands, South Orkneys, South Georgia and the coast of South America.

During the first quarter of the nineteenth century, elephant seal hunting was carried on chiefly by those engaged in fur sealing, but after the fur seals had been killed off some sealers continued their occupation of killing the elephant seal and boiling out the oil. The discovery of the Pennsylvania oil fields in 1859 brought a cheap illuminant on the market and gave the southern elephant seal some respite from the hunter. Nevertheless, at South Georgia, particularly, so many elephant seals were killed that they were practically extinct there by 1885.

Discouraged by the general scarcity of elephant seals and by inability to compete with the low production costs of petroleum products, southern sealing was largely abandoned before the close of the nineteenth century. With the revival of whaling in Antarctic seas, the Government of the Falkland Island Dependencies began in 1910 to issue licenses for the taking of elephant seals. These regulations seem to have obtained the desired result since Matthews in 1927 (1929, p. 246) estimated that there were at least 100,000 elephant seals on the South Georgia beaches.

SOUTHERN FUR SEAL

The first cargo of seal skins and whale oil exported from the Falkland Islands was carried by Bougainville's ship, the *Aigle*, in 1766 (Boyson, 1924, p. 219). Although the history of southern sealing during the ensuing decade is not very well known, there are indications that some whalers took seals as well as whales at the Falkland Islands.

When Port Egmont was evacuated by the British garrison in May 1774, 10 American sealing and whaling vessels were anchored in the Falkland Islands (Boyson, 1924, p. 235). Fur seals were present in such numbers on one of the smaller Falkland Islands that eight or nine hundred of them were killed on one day (Dalrymple, 1775, preface p. 9). The beaches of Saunders Island were reported by a French sealer in 1778 to have been lined with fur seals and elephant seals (Boyson, 1924, p. 235).

British sealers did not begin taking fur seals on these southern rookeries until the beginning of the American Revolutionary War, but were actively engaged in this fishery for at least 50 years thereafter. Shortly after the signing of the general peace treaty between Great Britain and the United States on September 3, 1783, the ship *States* sailed from Boston for the Falkland Islands and on arrival there anchored in States Harbor. For two years shore crews from this ship were engaged in taking skins of fur seals and sea lions, and in boiling out elephant seal oil. Thirteen thousand of the fur seal skins taken on this cruise were landed in New York and then shipped to China (Clark, 1887, p. 400). Subsequently, a number of vessels were outfitted in New England ports for this commercial enterprise. Among these were vessels from New York and Boston, one of which, the brig *Betsey*, returned to New York from the Falkland Islands in June 1793 with a full cargo of fur seal skins (Fanning, 1924, p. 13). Fanning in 1797 (1924, p. 261) found the rocks at the northeast head of Beauchene Island literally covered with fur seals. By 1812, however, fur seals had become scarce on all the larger Falkland Islands, but were still present in considerable numbers on Steeple Jason Island (Boyson, 1924, pp. 83, 236).

These adventurers sailed boldly in their small vessels to South Georgia, some 1,200 miles east of Cape Horn, where fur sealing was conducted with the same total disregard of the biological factors involved in the perpetuation of the stocks of seals. In the fall of 1800, 17 vessels arrived at South Georgia, and during the ensuing summer the shore crews landed by these vessels killed 112,000 fur seals (Fanning, 1924, p. 218). The corvette *Aspasia* of New York alone brought back 57,000 fur seal skins. James Weddell in 1823 (1825, pp. 53–54) calculated that no less than 1,200,000 fur seals had been taken at South Georgia since 1775. The records for South Georgia

show that 1,450 fur seals were taken in 1874, "great numbers" in 1877 (H. T. Allen, 1920, p. 108), and 170 in 1906 (Matthews, 1929, p. 255). These catches seem to have resulted in the final destruction of the South Georgia fur seal herd, although two were seen on Willis Island in 1927 (Matthews, 1929, p. 255).

So merciless was the slaughter of fur seals on the Falkland Island rookeries by a constantly increasing number of vessels and so keen was the race to reach unexploited beaches that British and American sealers were continually searching for new sealing grounds.

Sealers naturally were reticent regarding their findings, and in some instances several years elapsed before the news of their discoveries leaked out. Such seems to be the case with the South Shetland rookeries, located about 400 miles southeast of Cape Horn. Unconfirmed reports have circulated for nearly a century that American sealers had reached the South Shetland rookeries by 1812 (Calman, 1937, p. 176). Existing records do show that American and British sealers were slaughtering fur seals on these islands at least as early as 1819 (Ragged Island, Fanning, 1924, p. 304; Balch, 1909, pp. 474, 477; Bruce, 1920, p. 38).

To Col. Lawrence Martin, whose critical analysis of documentary data has contributed so much to the knowledge of the areas south of Cape Horn, I am indebted for the following information on the southern fur seal fishery in the vicinity of the South Shetland Islands. Shore crews from something like 50 sealing vessels, about equally divided between American and English registry, were killing fur seals on these rookeries during the Antarctic seasons 1820–21 and 1821–22. Sixteen of the American sealing vessels are known to have transported 160,000 fur seal skins to New York and New England in 1821. Nine English sealing vessels are reported to have shipped 165,000 fur seal skins to England. Thus the total catch for the Antarctic season 1820–21 could hardly have been less than half a million fur seals.

So ruthless was the exploitation of these fur seal rookeries, that by 1829 most of the financial backers of this sealing business considered the risks too hazardous to warrant voyages to the South Shetlands. At that time fur seals had been almost exterminated on all the accessible rookeries and the sealers were searching for new sealing grounds. Nevertheless, sealing continued with indifferent success for many years.

Forty years later (1871–72) sealers again came to the South Shetland Islands and in the ensuing 10 years killed off more than 90,000 fur seals there and on the rookeries east of Cape Horn (Clark, 1887, p. 402). The few remaining survivors of the Shetland Island rookeries seem to have been exterminated by a Vancouver sealer in 1905–06 (Anonymous, *in* Pacific Fisherman, vol. 4, No. 5, p. 20; No. 7, p. 19, 1906).

About 1790, British and American vessels engaged in sperm whaling along the coast of Chile, as well as others that had embarked in the maritime fur trade along the northwest coast of North America, observed large fur seal rookeries on some of the South American coastal and offshore islands. The American brigantine *Hancock* sailed from Boston, November 1790, for Staten Island. Many fur seals were killed by the crew on Staten Island before the brigantine rounded Cape Horn en route to Masafuera Island. Subsequently, this vessel stopped at the Hawaiian Islands and afterward sailed for the northwest coast of North America. After arrival there on July 14, 1791, the *Hancock* was engaged in trading with the natives for sea otter skins until she sailed for China in the autumn of 1791 (Howay, 1930, p. 122).

Masafuera, a small island lying 100 miles west of Juan Fernández, was one of the most important of these fur seal rookeries. On this island, a shore crew landed by the ship *Eliza* of New York in 1792 killed 37,000 fur seals, the skins of which were carried to Canton, China, and sold in March 1793 (Delano, 1817, pp. 196–197; Clark, 1887, p. 407).

A shore crew landed from the American ship *Jefferson* of Boston obtained 13,000 fur seal pelts on St. Ambrose Island during August and September, 1792 (Howay, 1930, p. 130). During 1793, the British sloop *Rattler* put into the Galápagos Islands for salt which was to be used in salting fur seal skins at St. Felix and St. Ambrose Islands, located off the coast of Chile some 500 miles north of Juan Fernández (Jenkins, 1921, p. 214).

From then on to 1807, the business of killing fur seals along the Chilean coast was prosecuted with unremitting vigor and at times shore crews from as many as 12 to 15 vessels had camps at Masafuera Island. Gangs of men put ashore in 1798 on Masafuera by three American vessels (ship *Barclay* of New Bedford, brig *Betsey* of Stonington, Conn., and ship *Neptune* of New York) killed some 60,000 fur seals. By 1801, the sealing fleet on the coast of Chile numbered upward of 30 vessels (Fanning, 1924, p. 223). A few of these ships carried 60,000, and one at least 100,000, fur seal skins to the market at Canton, China (Clark, 1887, p. 402), where they were exchanged for merchandise to be sold in the United States.

The rookeries on these islands had been so thoroughly ransacked in a period of 15 years that sealers could no longer expect to make a profit by going there, and by 1824 fur seals were practically exterminated on both Juan Fernández and Masafuera (Morrell, 1832, p. 130). Estimates of the number of fur seals killed on Masafuera and Juan Fernández Islands during this period range from a million (Fanning, 1924, p. 80) to more than 3 million (Delano, 1817, p. 306). Although the virtual destruction of this portion of the southern fur seal herd

was accomplished at the beginning of the nineteenth century, a few persisted for many years on inaccessible rocky ledges. As late as 1898, 50 fur seal pelts taken on Juan Fernández were sold in London (Cabrera and Yepes, 1940, p. 181).

Although the English sealer George Powell and the American sealer Nathaniel B. Palmer failed to locate any fur seals in December 1821 on the South Orkneys, this does not necessarily indicate that fur seals avoided these islands. There are no available records of fur seals having been taken on the South Orkneys during the period of unrestricted exploitation. Dallman, however, during the first 2 months of 1874 took 145 fur seal skins in the Sandefjord Bay district at the southwestern end of Coronation Island (Marr, 1935, p. 371).

Spanish sealers were taking a relatively small number of fur seals on the rocky islands along the Patagonian coast during the last decade of the eighteenth century. Yankee sealers, however, were constantly raiding these islands in defiance of prohibitions, but often in connivance with local officials. One such example was the ship *Neptune* of New Haven, which from January 1 to February 16, 1798, took some 5,000 fur seal skins from the rookery on a small island off Port Desire, Patagonia (Clark, 1887, p. 462–464).

Sealers rounding Cape Horn occasionally landed shore crews on Diego Ramírez, Staten Island, and other nearby small islands for the purpose of taking fur seals. It is evident that as late as 1828 fur seals were fairly numerous at the southern extremity of South America, since the schooner *Penguin* of Stonington, Conn., took 4,000 fur seals on Staten Island that year (Balch, 1909, p. 485). The schooner *Monticello* of Baltimore in 1833 and the schooner *Benjamin D'Wolf* of Newport in 1839 returned from islands around Cape Horn with cargoes of 2,500 and 2,000 fur seals respectively (Clark, 1887, pp. 451, 453). Intermittent slaughter of fur seals on these islands continued during the remainder of the nineteenth century. During the summer of 1882–83, the shore crew of the American bark *Thomas Hunt* salted down the pelts of 1,300 fur seals that had been killed on Diego Ramírez. No information of a later date on the condition of the rookery on this island seems to be available. Between 1882 and 1892, the crew of the ship *Nassau* was reported to have killed annually an average of 3,500 fur seals at Tierra del Fuego and neighboring islands (Cabrera and Yepes, 1940, p. 181). The last reported catch from rookeries near Cape Horn, and that only 936 fur seal skins, was carried to Nova Scotia in 1906 by the Vancouver schooner *Edith B. Balcom* (Anonymous, *in* Pacific Fisherman, vol. 4, No. 5, p. 20; No. 7, p. 19, 1906).

Aside from the rather ineffectual attempts of Spanish and Argentine governors to restrict the killing of the fur seals on the Falkland

Islands, fur sealing was never directly supervised by the governments in the Southern Hemisphere during the eighteenth and nineteenth centuries.

The rookeries on the Uruguayan coast, located for the most part on the Coronilla, the Castillos, the Torres, and the Lobos groups of islands, were leased to commercial sealers beginning in 1823. But here again, reckless commercial exploitation of these rookeries all but exterminated the animals. For the 35 years ending in 1907, the average kill of fur seals was nearly 15,000. In 1910, however, the Uruguayan Government commenced sealing on its own account and at the time of Dr. Hugh M. Smith's visit in December 1922, the rookery in the Lobos Island group was doubtfully estimated to harbor some 20,000 fur seals (Smith, 1927, p. 281).

Today only a few scattered individuals exist in the entire British Falkland Island Dependency Claim, a relatively small number of individuals have found refuge on the rookeries along the Uruguayan coast, and another small remnant maintains a precarious existence on islands along the coast of Peru.

No chapter in the story of wanton destruction of wild life contains so many obvious lessons as that of the southern fur seal fishery. It is now apparent that the values destroyed in the avaricious hunt for fur seals were many times greater than the moneys received from the pelts marketed, since the breeding stock that should have been maintained for the future harvesting of the annual surplus was destroyed on every accessible rookery. During the period of ruthless exploitation of the southern fur seal rookeries, the principles of wild life management were totally disregarded by the governments concerned, even though certain officials, notably Capt. James Weddell (1827, pp. 141–142), did not hesitate to call attention to the inevitable destruction of this economic asset if the practices then in vogue were continued. Conservation was either deemed impossible or not worth the effort.

Had scientific management of the southern fur seal herd been practiced at the inception of exploitation or at least before the rookeries had been seriously depleted, an adequate annual profit would have accrued to all the governments having jurisdiction over such rookeries. The devastating effects of this excessive slaughter have not passed unnoticed, but no serious effort has been made to remedy the existing situation. Nevertheless, it is not too late even today or impractical to attempt the restocking of fur seals on those rookeries, long since abandoned, where adequate patrol and protection can be maintained.

WHALING IN THE SOUTHERN HEMISPHERE

It may appear surprising that whaling in the Southern Hemisphere did not commence until stocks of whales in Arctic waters were markedly depleted. One contributing cause was the presence of pirates in

the West Indies. Another factor was the slow development of the practice of erecting try-works for rendering the oil on decks of whaling vessels.

Nevertheless, sperm-whaling sloops from New Bedford and other New England ports were cruising southward toward Bermuda as early as 1756 (Ashley, 1938, p. 37). Humpbacks and sperm whales, however, were taken by local residents of Bermuda, according to colonial records (True, 1904, pp. 27–29), during the years 1665, 1667, and 1668, and this fishery continued in a desultory fashion until 1749 or later.

These New England whaling ships while searching for sperm whales apparently did not cruise among the West Indian islands until after 1760, but sometime before 1770 one or more vessels crossed the Equator in the West Atlantic.

During the period between 1771 and 1775, there were from 121 to 132 American vessels engaged in the southern whale fishery (Jefferson, 1876, p. 6) on both sides of the South Atlantic. Sperm and right whales were hunted along the coast of Brazil from the Equator to off the mouth of La Plata River and thence southward to Le Maire Strait between Staten Island and Tierra del Fuego. Three of these Yankee whaling vessels, the brig *Montague* of Boston, the ship *Thomas* of Cape Cod, and the ship *King George* of Rhode Island, anchored at Port Egmont in 1774 (Penrose, 1775, pp. 67–70) and seven others not specifically mentioned by name were known to be elsewhere in the Falkland Islands that year (Jenkins, 1921, p. 235).

British whaling ships sailed for the coast of Brazil and the Falkland Islands in 1775. Before 1784, British vessels had made 76 voyages to these whaling grounds (Jenkins, 1921, p. 209). Six whaling ships with harpooners and crews from Nantucket were fitted out for the southern whale fishery in 1784 at Dunkirk, France (McCulloch, 1832, p. 1116).

British vessels, likewise with crews from Nantucket, rounded Cape Horn about 1788 (Starbuck, 1878, p. 90) and commenced sperm whaling on the coast of Chile. They were followed by American whaling ships which actively participated in the exploration of the Pacific and the exploitation of sperm whale stocks in those waters.

Hazards of capture during foreign and domestic wars, adverse conditions at home, variable insurance rates, restricted markets, and violent fluctuations in the market prices for sperm and whale oils kept the whaling business in a continual state of uncertainty.

Nevertheless, in the first half of the nineteenth century as many as five or six hundred vessels were employed in hunting sperm and southern right whales in the South Atlantic and Antarctic Oceans (Boyson, 1924, p. 220).

Shortly afterward the general scarcity of sperm whales became rather noticeable and the industry began its decline. Statistics for the year 1858 indicate that 68 ships were expected to return to Nantucket, Mass.,

with a total loss of a million dollars to the owners. A few of these whaling ships continued whaling after 1900, but the great days of the southern right whale and sperm whale fishery have long since passed into memory.

The rise, climax, and decline of the whaling industry has been reenacted time and again as the result of overfishing for particular kinds of whales, not only in the Southern Hemisphere but in all the waters of the world.

The modern period of whaling, however, began some 72 years ago with the invention of a swivel harpoon gun by a Norwegian named Svend Foyn. It was not the swivel gun alone, but the explosive head which was fitted to the harpoon that enabled the whaler to master the huge furrow-throated whales. The rope attached to the harpoon was strong enough to raise the carcass to the surface where it was inflated with air, so that it would float.

At the beginning of the twentieth century it became apparent that new methods of operating were necessary, if the industry was to avail itself of opportunities in more distant fields. Hence in 1904 an enterprising Norwegian operator converted the steamer *Admiralen* into a floating factory and began whaling around Spitzbergen. Having found that a floating factory was free to move as conditions required, the *Admiralen* began whaling operations in the Antarctic near the Falkland Islands in 1905. The whaling tackle used in this fishery during the first few years was not suited for taking such powerful whales as the blue whale, which reaches a length of 100 feet. Soon, however, whale-catcher boats with adequate equipment were built.

A modern whale catcher is a steamship somewhat similar to a trawler, but equipped with more powerful engines. It carries a crew of 13 to 19 men, including the master and gunner, and at least 1 cook, 2 firemen, 3 engineers, 6 sailors and a wireless operator, all of whom live in the most crowded quarters imaginable. Mounted in the bow of one of these boats is a maneuverable cannon that fires a harpoon weighing more than 100 pounds, and is fitted with strong hinged barbs that open after it has entered the body of the whale. The head of the harpoon also contains an explosive grenade that is fired by contact with the whale. The gunner, assisted by the lookouts in the crow's nest, scans the ice-filled waters of the Antarctic, the richest of all whaling grounds, for his quarry. When a whale is sighted the pursuit continues relentlessly until the victim is harpooned.

Once the harpoon has reached its mark, the whale is doomed, and although it may dive to some depth in its death throes, it is slowly but surely drawn to the surface by the steam winches of the whale-catcher boat. Usually the next step is to haul the dead whale alongside the whale-catcher boat where a hollow lance attached to a compressed-air hose is trust into the body in order to inflate the carcass so that it will

float. Then a flag is stuck into the carcass before it is cut adrift to be picked up later and towed to the factory ship. When two or three of these whales have been captured in this manner, they are towed to the factory ship or shore station, where their carcasses are dealt with promptly and efficiently.

During the first few years the floating factory ships were steamers of 2,300 to 6,000 tons. During this period also, the whales were cut up alongside the factory ships, and the blubber and the head were hoisted on board. For more rational use of the carcass these factory ships have been constantly improved. The large ships now in use are provided with a slipway, usually located at the stern above the propellers, on which the whale carcasses are drawn to the main deck by steam winches. Within 1 or 2 hours, the mammoth corpse is processed down to the last scrap of flesh.

The dead-weight tonnage of about half of the factory ships now in operation is around 20,000 tons. The *Terje Viken*, the largest of them all, is 633 feet long and is rated at 30,000 dead-weight tons. Ten whale-catcher boats are needed to kill sufficient whales to keep this factory ship operating 24 hours a day. Something like 418 men comprise the crew.

The perfecting of the kerosene lamp, of the gas mantle, of the electric light, and the deflating of women's garments gave the whales a respite for some years, but a sudden demand for the glycerine needed for the making of ammunition for the destruction of men gave the final impetus to these animals' fast approaching doom. Prior to World War I glycerine was a mere byproduct of the soap makers. Then came the enormous demand for this substance to be used in the manufacture of munitions. As whaling operations were necessarily suspended in the North Atlantic on account of the war, the active modern exploitation of the Antarctic field began.

Whale oil is now used principally for soap, with glycerine as a byproduct, for the manufacture of edible fats such as margarine in Europe, and to a lesser extent for leather currying, fiber dressing, face creams, unguents and ointments. In addition to this oil, a furrow-throated whale of average size will yield about 4 tons of meat, bone, and fertilizer. As a result of improved methods of pursuit and handling, as well as the discovery of new uses for whale oil in such things as margarine and cosmetics, the search for whales is now more active than ever.

The present century has witnessed large-scale killing of whales by relatively few ships. When World War I ended, it was expected that the demand for whale oil would drop off, but instead the total world production rose from 362,000 barrels in 1919 to 1,040,408 barrels in 1925. Since then the total Antarctic production of whale oil has increased year by year, the amount obtained in 1937–38 being

3,340,330 barrels. The bulk of this oil came from finback and blue whales. During 1937–38 alone, 54,664 whales were slaughtered, the largest number ever killed in one year. Of these, 46,039 were taken in Antarctic waters during the 97-day season extending from December 8 to March 15 by 256 whale-catcher boats operating with 31 floating factories and 2 land stations.

In the interval between 1904 and 1939, nearly 200,000 whales have been killed in the vicinity of the British Falkland Island Dependency Claim, which comprises South Georgia, South Shetlands, South Orkneys, and the Palmer Peninsula. Of these there were about 37,000 humpbacks, more than 75,000 finbacks, nearly 60,000 blue whales, about 4,000 sei whales, 590 right whales, and less than 1,000 sperm whales.

More than half of the 15,000 or more whales captured by shore stations and floating factories operating along the coasts of Chile, Peru, and Ecuador have been sperm whales.

The first clear indication that the stocks of whales in Antarctic waters were being decimated came during the season of 1936–37. For several years prior to that season, blue whales outnumbered finbacks two to one in the annual catches. The returns for the 1936-37 season revealed that for the first time more finbacks (14,381) than blue whales (14,304) were taken. The next year, 1937–38, 14,923 blue whales and 28,009 finbacks were caught. The same condition prevailed in 1938–39 when 14,081 blue whales and 20,784 finbacks were killed.

The blue whale has been the mainstay of the Antarctic whale fishery. This whale occasionally reaches a length of 100 feet and is the largest animal known to have lived on this planet. It has been calculated that the oil, fertilizer, and other products obtained from a 75-foot blue whale will equal that obtained from either two finbacks or two sperm whales totaling 110 linear feet, or from three humpbacks totaling 120 linear feet, or from four sei whales totaling 200 linear feet.

Much has been written regarding the enormous expansion of the whaling industry in recent years. Warnings have been given repeatedly that the scale of operations and the methods employed constituted a menace to the maintenance of the stock of whales. Whalers contended for some time, however, that the Antarctic circumpolar waters constituted a vast reservoir of whales and that those killed were replaced naturally by migration from inaccessible areas.

Nevertheless, some of the large whaling companies began to express openly some misgivings about the future of the industry if the promiscuous killing of whales continued unchecked. Shortly afterward, some of the governments, whose nationals were engaged

in whaling, expressed their serious concern at the increasing magnitude of whaling operations in the Antarctic, which had now reached such proportions that restrictive measures were urgently required if the future of the industry was not to be gravely endangered.

Although there were many difficulties in the way of adoption of such measures, it was recognized that, in the interests of conserving the stocks of whales, this could be accomplished only by international action. On April 3, 1930, a committee of experts met in Berlin at the request of the Economic Committee of the League of Nations to consider the feasibility of international regulation of the whaling industry. The draft convention prepared at this conference, after having been modified in certain minor respects, was ratified by 17 countries and acceded to by 8 others. This convention, however, did not come into force until January 16, 1935. By its provisions, full protection was given to all kinds of right whales; the taking or killing of calves, and females accompanied by calves, was prohibited; and the fullest possible use of the carcasses of all whales taken was required.

The first restriction in pelagic whaling operations, however, came in 1932, purely as the result of economic necessity. The whale oil market was glutted and the Norwegian fleet remained in port. The following season, influenced in part by the world financial crisis, all the companies, with one exception, agreed to restrict production to 2,000,000 barrels of whale oil.

Faced with the prospect that there would be no voluntary limitation of production during the 1934–35 season, the Norwegian Government found it necessary to consider amendments to the Norwegian Whaling Act to regulate the industry. It was recognized that the high standard of efficiency attained by the factory ships threatened the perpetuation of whale stocks. Consequently the Norwegian Whaling Act of 1934 conferred on the Crown the authority to restrict the whaling season to certain periods of the year, to enforce total utilization of the whale carcass, and to prohibit the killing of undersized whales.

In 1936, the Governments of Great Britain and Norway pledged themselves to curtail the season everywhere south of 40° south latitude to the 90 days between December 8 and March 7, and to limit the number of whale-catcher boats operating with each floating factory. Repeated conferences between officials of these two Governments led to the calling of the International Conference for the Regulation of Whaling held at London during June 1937. Stringent regulations, or "game laws," covering the minimum legal size for whales of each species, and prohibiting the killing of females accompanied by calves, as well as all right and gray whales, were drafted for approval by the Governments of South Africa, Argentina, Australia, Germany, Great Britain, Eire, New Zealand, and the United States. This agreement came into force as regards the United States on May 18, 1938.

Under the terms of this agreement, factory ships are barred from operation on the calving grounds of whales, and are obliged to make the fullest possible use of the whale carcass. Some minor modifications were written into the Protocol of June 1938, including the protection of the decimated stocks of humpbacks in Antarctic waters and the establishment of an Antarctic whale sanctuary between the Ross Sea and Cape Horn.

We are now witnessing what, without much doubt, is the last phase in the history of whaling, for after the culmination of the present exploitation of the Antarctic seas, where in the past 40 years more than 750,000 whales have been killed, no unexplored seas are left to be harvested.

If the exploitation of the whale stocks continues on the present scale, the time must soon arrive when the last remaining stocks of whales will be so depleted that it will be economically impossible to operate the great floating factories. One more of nature's bounties will have been sacrificed to man's greed.

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THE RETURN OF THE MUSK OX[1]

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[With 6 plates]

The musk ox, one of the most interesting mammals of the bleak Arctic, has returned to Alaska, and while little is known of its disappearance from that region more than a century ago, its return is boldly written in what is perhaps the most dramatic chapter in the annals of big-game conservation. Indeed, this remarkable undertaking of reintroducing a game animal into its ancient habitat has few parallels in conservation history.

To reestablish their kind in our northern territory, the musk oxen were transported by boat and by railway a distance of approximately 14,000 miles, the longest and most hazardous journey in the history of transplanting any mammal for restocking purposes. Captured in Greenland, the animals were shipped by boat to Bergen, Norway, and then to New York City. There they were crated and sent to Seattle, Wash., on express railway cars, to be loaded again aboard a boat for Alaska. More than 2 months were required to move the animals from Greenland to Fairbanks. Despite this record-breaking journey, the herd, consisting of 34 animals—15 males and 19 females—arrived at its destination in splendid condition.

This was in 1930. Nine years later, in 1939, when the herd was last counted on Nunivak Island, where it was released, it numbered 60. Biologists have full faith that the animals will continue to increase and in time be of sufficient number to permit restocking of other areas in Alaska.

But before reviewing this amazing undertaking, it may be well to consider the musk ox and its bleak habitat. The term "Arctic," to a great many people, suggests a desolate, ice-bound land—or water—where little life is supported. However true this may at first appear, there is error in such thinking. In our so-called Arctic wastes may be found a profusion of bird and mammal life in season, such as many

[1] Reprinted by permission from American Forests, August 1941.

species of migratory waterfowl, fur bearers, Arctic hares, lemmings, caribou, wolves, and musk oxen.

The greatest concentration of wildlife in the so-called Arctic wastes is to be found during the late spring and summer months, following which nearly all the mammals either hibernate or, along with the birds, migrate to a more suitable winter habitat. Of the mammals which neither hibernate nor to any great extent migrate from this chosen Arctic home, the musk ox is capable of contending with some of the bleakest habitats found anywhere.

This picturesque mammal was first discovered in North America by intrepid northern explorers and traders near the close of the seventeenth century. Although, as may be conjectured, the musk ox is related to wild and domestic cattle, it is generally smaller than most breeds, though some of the old animals have weighed 900 pounds. From the tip of its nose to the end of its short ratlike tail, the musk ox is nearly 8 feet long. As with most mammals of the cattle type, the adult bull is larger than the female. The young, one baby calf, is generally born in April or in early May, and this calf is reared in the valleys of the Arctic hills, mountains, and tundra flats. Here a profusion of sedges, grasses, and shrubs blossom in the fast-growing short spring and summer, and from these the herds with the young take their subsistence. These herds are generally small, averaging from 5 to 12 animals.

Arctic summers usually disappear with great suddenness, leaving little semblance of an autumn, and early snows cover much of the musk ox's food. With this quick disappearance of fresh grasses the mammal turns to dwarf willows, saxifrage, and other herbaceous plants and grasses which it obtains by pawing through the snow with its broad hoof.

Two of the natural enemies of the musk ox have been the Arctic wolf and the isolated tribes of primitive man, such as the Eskimo and the Indian. Against these enemies this interesting and formidable appearing Arctic creature held its own in fair numbers. The modern firearm, however, coupled with predation and the take by the northernmost tribes, spelled its doom.

Originally, musk oxen occurred from Alaska eastward to and including Ellesmere Island. Crossing Baffin Bay, and still eastward, it was again encountered in the coastal fringes of Greenland. Adolphus W. Greely, leader of the famous Greely Arctic Expedition in the early eighties, found the animal near old Fort Conger, approximately 1,100 miles north of the Arctic Circle, on Ellesmere Island, and points westward. Greely's men captured calves and attempted to tame them, with the result that some became docile and tractable even to the extent of hauling in teams. The chief difficulty was to keep the sledge dogs of the expedition from killing them.

Today the musk ox has disappeared from much of its original Arctic domain. The use of modern firearms against the musk ox, which began 40 years prior to the advent of the present century, has been the greatest contributing factor. For a time its skin was utilized in the fur trade; northern whaling crews killed many animals for food; then the formidable heads with sharp, curved horns became highly prized as trophies. Canada, taking cognizance of this condition, some years ago set up a musk ox sanctuary of approximately 15,000 square miles along the Thelon River east of Great Slave Lake in the Northwest Territory.

Research has failed to find any authenticated occurence of the musk ox in Alaska since it was first explored by Europeans. The various tribes of natives in the Territory, however, state that the animal did occur there about 100 years ago. Also, remains of the mammal have been found in Alaska; and it is known that portions of the Territory are suitable for musk oxen.

So, in 1927, resident Alaskans presented a memorial through their Territorial legislature addressed to the Senate and House of Representatives of the United States requesting funds to purchase a small herd of musk oxen. This plea came to the attention of the late Senator Peter Norbeck of South Dakota, that grand old man of conservation, and Representative C. C. Dickinson of Iowa, later a Senator from that State. Together with Irving McK. Reed, then a member of the Alaska Game Commission, they obtained favorable action by Congress for an appropriation of $40,000 to be used in obtaining a herd of musk oxen and transporting the animals to Alaska for restocking purposes. This action was approved by the President on May 27, 1930. The agency of the Federal Government to which this undertaking was entrusted was the Bureau of Biological Survey of the Department of Agriculture, later transferred to the Department of the Interior, and during the past year combined with the Bureau of Fisheries into an organization known as the Fish and Wildlife Service.

By the time the appropriation became available musk oxen in North America had become so reduced in numbers that it was impossible to obtain surplus animals. Finally, contact was made with Johs. Lund of Aalesund, Norway, who was familiar with the technique of capturing musk oxen alive in Greenland. To him, therefore, was given the contract and task of rounding up a herd of 34 animals. The Greenland musk oxen differ somewhat from those that formerly occurred on the continent of North America, foremost in that they are slightly smaller. However, from a practical game-management standpoint, the differences are negligible.

The majority of these Greenland musk oxen were roped by Mr. Lund and transferred from the mainland in whaling boats to a ship

which carried them to Bergen, Norway. They were placed in specially constructed crates which permitted the animals to stand or to lie down in comfort. Grasses and hay taken in the locality of their capture provided suitable food.

On September 6, 1930, the herd of 34 animals, half of them calves, the remainder yearlings and 2-year-olds, was shipped from Bergen and 10 days later arrived in the port of New York. From there they were removed to Athenia, N. J., where for 33 days, in accordance with Federal regulations, they were held in quarantine. This procedure was necessary to be assured that such diseases as foot-and-mouth disease and rinderpest were not present in the herd. During this interval two experts from the Biological Survey were placed in charge of the animals, and American-grown alfalfa hay became their main food. About 5 pounds of hay an animal were consumed daily along with considerable water, the latter probably caused by excessive heat on the Atlantic seaboard and, in addition, to thirst caused by the great environmental change.

At the end of the quarantine period, the animals, still in their individual crates, and well supplied with hay and water, were loaded into steel express cars for their 5-day trip to Seattle. At this point they were again placed aboard a boat for the week's journey to Seward, Alaska; then in freight box cars, they made the rail trip northward to College, near Fairbanks. They arrived at this destination on November 4, and on the following day, near the campus of our most northerly institution of higher learning, the University of Alaska, were released into a 7,500-acre pasture—part of the Biological Survey's cooperative reindeer experiment station. This was to be their home for the following 6 years—years of care, study, and experiment. All the musk oxen reached College in splendid condition.

Accidental injuries reduced the herd to 32 animals shortly after it was placed in the pasture. These, however, soon responded to handling and could be driven easier than reindeer when it was desired to corral them. While under observation at this point, it was found that in spring and fall the animals fed chiefly on grasses and sedges, in summer on shrubs, and in winter on cured grasses, sedges, and, to some extent, on lichens. By 1932, the herd was further reduced, 2 of the animals falling victims to bears.

In April 1934, the first of the calves were born, and in May and June additional calving took place. There were nine 5-year-old cows at this time and seven of them gave birth to calves. Four cows that were 4 years old did not breed. Of the original 34 animals brought to Alaska, 10 had died by 1934, leaving 24 of the original herd and 5 new calves, a total of 29. Additional calving during the spring of 1935 brought the herd to 32.

It was ascertained up to this time that apparently the musk ox does not breed until 4 years of age, and calves at 5 years. It was also found that the gestation period is 8 months rather than 9 months, as previously believed.

In the summer of 1935 the first of these musk oxen, two adult bulls and two adult cows, were liberated on Nunivak Island in the Bering Sea. Unfortunately, a third cow was killed en route. This island lies approximately 25 miles from the mainland and south of the mouth of the Yukon River. It is about 40 miles wide and 70 miles long, containing nearly a million acres of superb grazing land. Also, the island is completely free of all predators, such as bears and wolves.

In 1936, when checks indicated the four animals were doing well, it was determined to liberate the remainder of the herd there. The animals were accordingly rounded up and crated—27 in all. By this time the youngsters trapped in Greenland had matured into real animals, and it was with difficulty that they were captured. They were hauled by trucks and freight cars to Nenana, from which point they were transferred to the engine deck of the S. S. *Nenana* for the long trip down the Yukon River. Arriving at Marshall 4 days later, the animals were reloaded to a covered barge and, towed by motorship, resumed their journey down the Yukon to its mouth, at Kotlik, thence across Pastol Bay in the Bering Sea to St. Michael. Here they were placed on an open barge, the crates covered with tarpaulins, being lashed with cables to prevent shifting of the load. On July 14 the barge, in tow of a motorship, headed for the open sea and Nunivak Island.

At this time of year northern Alaska may be visited by sudden and severe storms, so there was great anxiety on the part of those of us directly concerned with the movement and management of the animals. Three men were assigned to the barge, one to look after the barge itself, the others to care for the comfort of the musk oxen. From the words of one of these men, some idea may be had of the hazards involved in this dramatic trip:

> In letting out the towline, it fouled on an object in the bottom of the bay, perhaps an old 1,000-pound anchor, which was dragged out to Stuart Island, a distance of about 15 miles, before being dislodged. Heavy seas were encountered outside of St. Michael Bay, and until we reached the shelter of Stuart Island the going was rough. The weight on the towline pulled down the bow of the barge and prevented it riding over the waves, so it plowed through them. The barge was put to considerable strain these 3 hours. After freeing the towline the barge rode more smoothly.
>
> When we reached the open sea the barge began to reveal its age. The drift bolts in the bow parted, opening a seam its full width, through which the water poured each time it hit a wave. Other seams began to open, and by 9 a. m., the water stood 3 feet deep in the well of the hold.

Hand pumps were resorted to and the speed of the towing ship was reduced until a stop was made in the lee of Sand Islands. Here the barge was repaired, and on July 16, the journey resumed to Nunivak. By early in the evening of that day, anchor was made on the east side of the island, a few miles south of Cape Etolin.

A number of Eskimos live on Nunivak Island, and through the active interest of Carl Lomen, the well-known conservationist, of Nome, Alaska, their cooperation was obtained, and the unloading of the animals was completed on July 17. The head man on Nunivak Island, well known as trustworthy by Mr. Lomen, had a radio receiving set. In order to insure additional manpower that might be vital to success in unloading the musk oxen under adverse conditions, Mr. Lomen broadcast a message to the island three times a week over a lengthy period prior to the anticipated date of arrival. The weather fortunately held good, which enabled the men to place the barge well inshore. From this position gang planks were placed onto dry land, and down these planks the crated musk oxen, one by one, were shoved. Released from their crates, the animals soon took to their new and permanent home. A reconnaissance of the island proved that the four musk oxen released in 1935 were definitely established. A check of the island in 1939 revealed that the initial stock of 34 animals received at College from Greenland in 1930 had multiplied to more than 60.

Thus Alaska has her musk ox once again, after probably the longest and most hazardous journey in the history of transplanting any mammal for restocking purposes. The total distance these animals traveled was approximately 14,000 miles. But a sudden storm might have wrecked all the fine work that was so vigorously and effectively sponsored by Senator Norbeck and Representative Dickinson 6 years previously—in fact, wrecked the whole venture and caused the loss of human life. But such is the risk many enthusiasts in wildlife conservation are willing to assume.

It is hoped that as the Nunivak herd continues to increase a surplus will be produced. This will permit the restocking of other Alaskan areas containing suitable habitat where this interesting mammal of the bleak Arctic may live and breed and thus perpetuate its kind again over much of its old range in that romantic territory.

1. METHOD OF CAPTURING THE YOUNG MUSK OXEN IN GREENLAND.
Some were calves, others were yearlings.

2. A MUSK OX ABOUT TO BE CRATED IN GREENLAND PREPARATORY TO ITS LONG TRIP TO ALASKA VIA THE UNITED STATES.

1. UNLOADING LIVE CRATED MUSK OXEN ON ARRIVAL AT ALASKAN DESTINATION, 1931.

2. HEAD VIEW OF 4-YEAR-OLD MUSK OX BULL, ALASKA, MAY 6, 1934.

MUSK OXEN ON FEED LOT.

Upon their arrival in Alaska from Greenland the herd was placed in a 7,300-acre pasture near College for observation. Here, 2 years later, the animals demonstrate their picturesque battle formation used against attacks by wolves, bears, and other enemies.

1. ANIMALS ARE LIBERATED AFTER THEIR 14,000-MILE JOURNEY.
This cow was reluctant to leave her crate even after it was flooded by the incoming tide.

2. IN 1934, WITH THE HERD STILL IN THE COLLEGE PASTURE, THE FIRST CALVES WERE BORN.

1. IN 1936 THE MUSK OXEN WERE CRATED AND PLACED ABOARD A LARGE BARGE FOR THEIR LAST VOYAGE.

2. CLIMAXING ONE OF THE MOST DRAMATIC CHAPTERS IN THE ANNALS OF BIG GAME CONSERVATION, THE BARGE AND ITS CARGO OF MUSK OXEN APPROACH NUNIVAK ISLAND IN THE BERING SEA.

1. A 5-YEAR-OLD BULL, ONE OF 34 ANIMALS THAT MADE THE LONG TRIP TO ALASKA

2. AFTER 100 YEARS THE MUSK OXEN HAVE RETURNED TO ALASKA, WARDS OF THE FEDERAL GOVERNMENT.

On Nunivak Island in the Bering Sea the small herd trapped in Greenland 11 years ago has now grown to more than 100 animals, and biologists believe that in time their number will be sufficient to permit restocking of other areas.

INSECT ENEMIES OF OUR CEREAL CROPS

By C. M. Packard

Principal Entomologist, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, U. S. Department of Agriculture

[With 10 plates]

To the casual observer the growing of cereal crops such as corn, wheat, and oats seems to be a very simple procedure. We accept our daily bread—as well as our meat, milk, and eggs—with little thought of the labor involved and the difficulties surmounted in placing these essential foods on our tables. In these days of urban industrial life two-thirds of the population have forgotten, if they ever heard, the old rule for planting corn: "One for the squirrel, one of the crow, one for the cutworm, and one to grow." Nevertheless, with all our modern improvements in farming, the crop losses recognized in this old adage still occur, even though ways of reducing these losses are gradually being found.

LOSSES AND SAVINGS

The 25 percent loss of crops implied by this old saying as being due to insects is much too high for a general average, although almost total losses are caused annually by one insect pest or another in occasional fields. An annual reduction due to insects of about 10 percent in crop yields is, however, considered a conservative estimate. Even this much reduction may mean the difference between profit and loss from a whole year of labor by an individual farmer. Moreover, in these days when so many men are fighting instead of producing and when they, as well as our allies, must be fed if the war is to be won and starvation is to be prevented, the toll taken by the insects as well as our other enemies increases in importance. The 10 percent of our normal production of staple crops taken annually by insects would far more than feed all our fighting forces and would go far toward supplying the food needed by our allies.

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The following figures are carefully considered estimates of average annual losses due to the most injurious species of a long list of insects that attack cereal crops:

Insect	*Crops affected*	*Annual losses*
Corn earworm	Corn	$79,200,000
Hessian fly	Wheat	13,018,000
Chinch bug	Corn, wheat, rye, oats	15,000,000
Grasshoppers	Cereal and forage crops	25,701,000
European corn borer	Corn	5,000,000
Sorghum midge	Sorghums	6,401,000
Rice stink bug	Growing rice	500,000
Rice weevil	Stored corn, wheat, and rice	65,042,000
Other stored-grain insects	All grains	300,000,000
Total		$509,862,000

Very few satisfactory estimates of the value of crops saved through the application of control measures have been made. Definite figures on this subject are extremely difficult to obtain. They are available, however, for a few Federally supported and organized programs to protect crops from certain insect pests. For instance, in 1934 it was estimated that through a combined Federal and State expenditure of $1,212,776 in a cooperative effort to control the chinch bug, at least $25,500,000 worth of corn was saved from destruction. Thus, for each dollar expended approximately $21 worth of corn was saved.

Publicly supported grasshopper-control campaigns also afford examples of the crop savings realized from insect control, as shown by the following figures on recent operations.

	1939	1940	1941
Bait used ... tons, dry weight	153,811	66,765	21,041
Estimated total expenditures by all cooperating agencies ... dollars	5,609,322	2,079,790	801,020
Estimated value of crops lost ... dollars	46,802,379	22,897,796	23,822,713
Estimated value of crops saved ... dollars	128,488,725	42,690,513	35,553,158
Value of crops saved per dollar spent	$22.90	$20.65	$44.42

These savings have been largely due to Federal and State research work on the development, improvement, and application of grasshopper-control measures and serve to illustrate the value of such research. An average of $2,229,714 has been expended annually by the Department of Agriculture during the fiscal years 1938 to 1942, inclusive, in research directed toward the control of the insects affecting man and his food crops. At this rate it thus becomes evident that the value of crops saved in the single year 1939 from grasshoppers alone has repaid for more than 57 years of research work conducted by the Department on all the great variety of noxious insects that beset us. Moreover, with the application of insect-control

measures discovered by research, not only for one year but for many years, the returns become continuous and enormous as compared with the original cost of finding and perfecting them.

MODES OF INSECT ATTACK

Like human armies, insects attack in a variety of ways. There are the aviators, the ground troops, the subs (though subterranean rather than submarine), and the borers from within, all in most efficient combination. What they lack in size is more than made up in numbers. They attack our cereal crop plants underground, bore within them or eat the leaves or grain during part of their lives, and then become aviators for purposes of infiltration and advance. White grubs, wireworms, and rootworms gnaw the roots of grain crops, change to actively flying beetles in their adult stages, efficiently select favorable locations for the next attack by their underground progeny, and plant time bombs in the form of eggs which hatch into most effective sapper battalions. The adult moths of corn earworms, corn borers, and armyworms; the adults of the hessian fly, jointworm, and sawflies; and the winged adults of chinch bugs, and grasshoppers, fly from field to field—some of them for much longer distances—and locate their ground troops of borers and scorched-earth specialists in the most advantageous positions for crop destruction.

In their ability to change from one form to another, and to live off the country, the insect enemies of our cereal crops are in some ways more efficient than we or our human enemies. This ability greatly complicates the problem of fighting them, since only in certain stages of their insidious, versatile, and persistent attack can they be fought successfully. Furthermore, the methods of defense usable against them are limited by the low value per acre of these crops. Even though in the aggregate the cereal crops are by far the most essential and valuable of our farm products the returns per acre to the individual grower are in general comparatively small and he cannot afford expensive measures for control of the insects attacking them.

METHODS OF REPELLING INSECT ATTACKS

Painful experience and painstaking study have, however, shown many ways of overcoming these pests. Fortunately for us, each species always follows about the same tactics and usually there are one or more vulnerable points in the course of their activities at which they can be attacked successfully. In some instances no highly effective and practical means of overcoming them have yet been found, and in others a combination of several control measures is necessary in order to subdue them. Obviously, the first essential in the control of an insect is a thorough knowledge of its life history and habits in

relation to the cultural methods required for the crop or crops on which it feeds. With this knowledge as a basis we are in a position to determine what measures can be utilized in its suppression, such as changes in time of planting the crop; changes in the succession of crops in the rotation; best tillage methods and best time to apply them; timely destruction of crop residues; use of mechanical devices, barriers, and insecticides; and the discovery or development of resistant varieties of the crops attacked.

CULTURAL CONTROL MEASURES

Variations in the cultural procedures ordinarily followed in growing the particular kind of grain attacked may often be utilized in preventing injury to that crop by certain insects. Control measures of this type are especially desirable because they add little or nothing to the expense of growing the crop. One of the most effective means of preventing the hessian fly (pls. 1–3) from attacking winter wheat, for instance, is to delay the sowing of the crop in the fall just long enough so that it does not come up until the fall flight of the insect is past. Moderately late plantings of corn are less seriously damaged than early plantings by the rootworm or "budworm" (pl. 4) in the southeastern States, and by the European corn borer in the northeastern States. Again, midseason (May) plantings of corn in southeastern Texas are better able to survive the attack of the sugarcane borer, a serious pest of corn in that area, than early or late plantings, because they escape the first brood and attain enough growth before the advent of the second and later broods to withstand them more successfully than late plantings do.

The proper disposal of crop residues is often helpful in the control of certain insects, and highly important in the control of others. The European corn borer survives the winter in the full-grown caterpillar stage, chiefly in the stalks of corn and coarse-stemmed weeds. In late spring or early summer the caterpillars change to moths which fly to the new corn for egg laying. Complete disposal of the plant residues in which the borers overwinter, by plowing them under (pl. 5), feeding them to stock, or burning them before the spring emergence of the moth, is one of the most important control measures for this insect. The sugarcane borer has similar habits in sugarcane, sorghum, and corn, except that the warmer climate along the Gulf coast where it occurs causes the adult moths to emerge earlier in the spring; hence fall or winter disposal of the residues of these crops is helpful in the control of this insect also. In the case of several wheat-infesting insects, e. g., the hessian fly, jointworm (pl. 4), strawworm, and sawfly, the plowing under of the wheat stubble during the summer or early fall prevents their emergence to infest the new crop, or to breed

and multiply in the volunteer wheat that would otherwise grow in the stubble fields.

Certain tillage practices may sometimes be utilized in breaking the annual cycle in the development of certain species. Plowing, for instance, may be extensively and profitably applied in the control of grasshoppers. These insects are not as improvident as Aesop's fable about the grasshopper and the ant would imply. During late summer and early fall most species deposit their egg pods in the ground (pl. 8), sometimes in enormous numbers, and thus having provided for the succeeding generation, die naturally of old age. The eggs normally remain well protected in the soil until the following spring without need of any food supply. In fact, the common injurious species spend 6 to 8 months of the year as eggs in the top 3 inches or so of soil. If, sometime during this long period, preferably in the fall, the soil is turned over by plowing to a depth of at least 5 inches and the surface layer well compacted by subsequent cultivation, the little hoppers hatching from the eggs can be effectually prevented from emerging.

The pale western cutworm, a serious pest of small grains in the Great Plains, provides another example of how knowledge of an insect's habits may lead to inexpensive and practical cultural control methods. It is known that most cutworms hide in the soil during the day but come out to crawl around on the surface at night. They can be cheaply and easily controlled, therefore, by spreading poison-bran bait in the infested fields, the worms eating it during the time they spend above ground. But the pale western cutworm cannot be controlled by this method because it stays underground both day and night, and progresses from plant to plant by burrowing along just underneath the surface. A Canadian investigator discovered, however, that these worms quickly die after they hatch out in the early spring if the newly sprouted vegetation is all killed by thorough cultivation as soon as the worms have had a little time to feed. Strangely enough, they can survive for some time if they have had no food, but die quickly if they have once fed and are then deprived of food. The infested fields may therefore be cleanly fallowed for about 3 weeks soon after the worms have hatched, and then sown to spring grains with little subsequent injury to the crop, which otherwise would have been ruined by this cutworm.

A different strategy has also been used successfully against the pale western cutworm in the southern Great Plains where fall-sown wheat is the principal grain crop. In studying the insect's habits it was discovered that the adult moths, which emerge in the fall, tend to fly to, and lay their eggs in, fields or portions of fields that had been allowed to produce a growth of vegetation during the summer. Winter wheat sown in such fields was severely injured by this cutworm

the following spring, while fields that had been cleanly fallowed prior to seeding escaped injury.

Rotation with other crops is often used to great advantage in preventing injury to cereal crops, especially by certain species with restricted food habits. The larvae of June beetles, commonly called white grubs (pl. 14), are partial to crops belonging to the grass family and, by gnawing their roots, cause serious injury to pastures and grain crops planted on land that has been in sod. Leguminous crops, on the other hand, are unfavorable to their development, and the proper use of legumes in the rotation, or in combination with grasses in pastures, serves to reduce their depredations to negligible proportions.

The corn rootworm (pl. 4), a serious pest in the Corn Belt, and the grape colaspis, another enemy of both corn and soybeans in that region, often become extremely abundant in fields that are planted to corn or soybeans for 2 or 3 years in succession. These insects are very restricted as to food plants, however, and can be readily eliminated as serious factors by crop rotations that are not only effective for this purpose but also are good general farm practices.

Suitable crop rotations are also very useful as auxiliary preventive measures against several insects such as the hessian fly, strawworm, jointworm, and sawfly, which frequently cause serious injury to wheat.

Crop rotations and intensive farming, on the other hand, may be favorable to some insects, such as the chinch bug (pl. 12). This is a native American insect which probably fed on certain wild prairie grasses and was of no consequence before the native sod was plowed and planted to crops. The settlement of the prairies and the almost complete utilization of large areas for the production of grains provided the chinch bug with crops much to its liking. An abundance of wheat and other small grains for the early summer brood to feed upon, and great acreages of corn in close proximity on which to finish its growth and produce one or more additional broods during the season, were ideal for its multiplication, with the result that it immediately became and has since remained one of our worst grain pests. Much can be done toward its control, however, by modifying the farming system so as to break the continuous rotation and the proximity of corn and small grains so favorable to the chinch bug, through the use of leguminous crops and pastures.

Other cultural measures inherent in good farm practices, such as the use of fertilizers and soil-building crops, the planting of the new crop as far away as possible from the fields that bore the same crop the previous year, and the use of the best adapted and most vigorously growing varieties are all helpful as auxiliary measures for the control of cereal crop pests. Since most of these are, in themselves, profitable

procedures, no added expense to the farmer is involved in obtaining the added protection from insects which they afford.

MECHANICAL CONTROL MEASURES

The mechanical devices used for the control of insects attacking cereal crops are confined mostly to the ordinary farm tools, which, however, rather than having any direct effect on the insects themselves, are chiefly effective indirectly through their use in cultural procedures and cropping systems. Plowing and disking do, of course, kill a considerable proportion of certain soft-bodied insects, such as the white grubs, cutworms, earworms, and rootworms, particularly if done at a time when they are changing from the worm to the adult beetle or moth stage in their underground pupal cells. The indirect effect of plowing under corn residues containing corn borers and soil containing grasshopper eggs to prevent their emergence has already been mentioned. In these cases, however, the benefits are derived mainly from the burial of the insects rather than from the mechanical action of the plowing. In general, the direct mechanical effect of the ordinary soil-working tools is of minor importance in the control of the insects injuring cereal crops.

The rotary plow should perhaps be mentioned as an exception to this statement. This machine has a power-driven horizontal cylinder bearing a series of blades somewhat like a lawn mower. It not only turns over the soil but chops it finely, together with any insects, such as white grubs, it may contain and has been reported to be very effective against soil-infesting insects. Because of the high cost of operation and the impracticability of using it in stony ground, however, it has not come into general use.

With the exception of equipment for the application of insecticides, the development of special mechanical devices for the direct control of insects has been very limited. In this field the development of machinery for the destruction of European corn borers has been most thoroughly investigated. As a result of intensive cooperative work by agricultural engineers and entomologists several useful forms of equipment have been devised or adapted for corn-borer control. These include low-cutting attachments for corn binders and harvesters, hand cutting hoes and stalk shavers (pl. 7) for use in low-cutting of corn to be shocked by hand or corn stalks to be plowed under, shredding and chopping attachments for mechanical corn pickers, stationary husker-shredders, silage cutters and field silage harvesters, and stationary fodder cutters and grinders. Although little of this machinery has yet come into general use, with the increase of the borer in the main Corn Belt it may be used extensively after the war, when materials essential in its manufacture are available.

In the field of development of mechanical insect-control devices attempts to produce a practical grasshopper catcher or "hopperdozer" have been many and varied, and have been more or less continuous since the great outbreaks of the Rocky Mountain locust soon after the Civil War. Certain of these machines are fairly practical for the control of some species on some crops and under certain conditions, especially since the advent of motor trucks and tractors to which they can be attached and by which they can be run rapidly over the infested fields. Even the best of them are not very efficient, however, and the use of "hopperdozers" has been almost entirely superseded by the cheaper and more efficient poison-baiting method of control.

INSECTICIDES AND REPELLENTS

By far the most extensive uses of insecticides for cereal insects are in the form of baits for grasshoppers, armyworms, and cutworms attacking these crops in the field; and of fumigants for moths, weevils and related insects attacking grain or cereal products during storage or milling.

Before the advent of poison-bran bait the farmers were at as great a disadvantage against several of these insects as were the Indians with their bows and arrows against the American pioneers equipped with rifles. Cultural methods of one kind or another, most of which are preventive rather than remedial, and which, to be effective, must be applied before the crop is actually planted, were practically the only recourse of the farmer. Even the best informed and most foresighted farmers were more or less helpless in the face of the periodical outbreaks of one or another of these insects that occur when conditions favor their increase for a season or two. Many less well informed farmers devoutly believed that a visitation of armyworms or grasshoppers to their fields was divine punishment for some transgression of which they might not even be aware.

POISON BAITS

The first recorded use of poison bait against grasshoppers was in the 1880's by farmers in the San Joaquin Valley of California. Doubtless the first farmer to try it was considered by his neighbors to be rather weak-minded if not crazy to expect the hoppers to pay any attention to a thin sprinkling or a few little heaps of poisoned bran in competition with their natural food plants. Nevertheless, the scheme worked surprisingly well. It was improved by the substitution of wheat bran for middlings and called to the attention of farmers and entomologists in other parts of the country by D. W. Coquillet, a noted investigator of that day in the field of insect control, who first observed its use in California.

With recurrent grasshopper outbreaks in many other States the method gradually came into much wider use (pl. 10) and its effectiveness against armyworms and cutworms as well as grasshoppers became more generally known. Many attempts were made to increase the efficiency of the bait by the addition of flavorings of one kind or another, such as cane molasses, ground citrus fruit, or banana oil, to make it more attractive to the grasshoppers. Up to the present time, however, the wheat bran itself, and products closely related to it, have proved to be about the most attractive, most widely available and cheapest material suitable for large-scale use. The effectiveness of bran baits has not been increased enough by any other attractants yet found to warrant the trouble and cost of adding them. On the other hand, it has been found possible to dilute the bran greatly with cheaper inert flaky substances, particularly wood sawdust or cottonseed hulls, without materially reducing the efficiency of the bait. As a result of this discovery the cost of bait per acre has been much reduced and the funds available for control operations have been made to go much farther in recent years than formerly. The quantities of bait used during the years 1939, 1940, and 1941 for the control of grasshoppers, and the crop savings realized thereby are given in the table on page 324.

Large quantities of bait have also been used during the past several years in the control of armyworms and Mormon crickets. It is only within the last 3 or 4 years that bait has been used successfully against the latter. Although the Mormon cricket (pl. 11) is really a big wingless grasshopper and likes the same crops, it will have little to do with the standard bait in which an arsenical is used as the poisonous ingredient. For many years this was thought to be due to all sorts of reasons except the right one. Finally Cowan and Shipman learned from their experiments that the crickets refuse to eat baits containing an arsenical even in extremely small quantities but that they will take them readily when sodium fluosilicate is substituted as the poisonous ingredient. This discovery has resulted in much cheaper and more effective control by baiting than was possible by any of the methods previously used, which included dusting the crickets with sodium arsenite and the installation of barriers and traps of one kind or another (pl. 11) to dispose of the migrating bands.

Sodium fluosilicate bait is also just as effective against grasshoppers as the arsenical bait and, owing to the scarcity of arsenicals as a result of war conditions, is supplanting it in grasshopper-control operations. Fortunately, no scarcity of sodium fluosilicate has yet developed. Another very valuable feature of the fluosilicate is its distastefulness to livestock and the probable elimination through its use of the accidental poisoning of stock which sometimes occurs as the result of carelessness in the handling of arsenical bait or sodium arsenite dust.

In the large-scale publicly supported campaigns of recent years, the

control of grasshoppers, Mormon crickets, and armyworms has been greatly increased in scope and efficiency by the invention and wide use of motorized equipment (pl. 10). The invention and use of power bait-mixing machines, traction and power bait spreaders, the use of motor trucks for hauling bait, and the adaptation of airplanes for its rapid application, especially on terrain not readily treated by ground equipment, have all contributed wonderfully to the practicability and effectiveness of large-scale control operations against these insects.

CHEMICAL AND MECHANICAL BARRIERS

The habits of certain of the insects attacking cereal crops are such that chemical or mechanical barriers, or a combination of both, may be used to good advantage in their control. The chinch bug is a good example. This insect is one of the worst pests of corn in the main Corn Belt. When weather conditions are favorable it develops in enormous numbers in the small grains during the spring and early summer, sometimes seriously injuring considerable acreages of them. The small grains usually ripen before the spring brood of bugs attains the winged or adult stage and the immature bugs then migrate on foot from the small-grain fields into the nearby fields of young corn. If this migration is not stopped immediately the complete destruction of the corn may be only a matter of days. Fortunately for the farmers, however, the bugs must migrate by crawling instead of flying; hence, it is possible to stop them effectively by means of a barrier of some kind (pl. 12). One of the best barriers is a line of coal-tar creosote placed across their line of advance, applied directly on a smooth, hard-packed low ridge of earth or on a fence about 2 inches high made of heavy paper. The latter method is the more efficient. Post holes to serve as traps are then dug about every 20 feet along the side of the barrier toward which the bugs are migrating. Creosote is very repellent to chinch bugs, and they will not cross the barrier line as long as it is kept in good condition. Instead, they travel in streams along it until they fall into the post holes where they are killed. With the prompt installation and proper maintenance of these barriers the corn can be completely protected.

But here again we encounter another instance of the far-reaching effect of the present war. It has created a scarcity of coal-tar creosote that may make this material difficult, if not impossible, to obtain for chinch-bug control. Anticipating this situation, however, both State and Federal entomologists have been experimenting with possible substitutes and have succeeded in finding several very promising ones. Some of these may prove to be even better than creosote and applicable to the corn itself, in case of need, as well as to barriers.

Before repellent chemicals came into use for chinch-bug barriers a simple mechanical type of barrier was widely used, consisting of

furrows or strips across the line of march of the bugs, in which a deep, dusty mulch was produced by continuous dragging of a log back and forth in the furrows, or by harrowing the strips. The dust and the dragging or harrowing together effectually prevent the bugs from getting across such barriers in injurious numbers. This type of barrier, however, has two serious disadvantages: The continuous attention it requires, and the impossibility of maintaining it in wet weather.

The barrier idea has been utilized in a much different way in the control of the corn earworm (pl. 17). As many people know who have raised sweet corn or have husked ears preparatory to cooking, these greenish or brownish worms eat their way down through the tip of the ear and the kernels, making very messy burrows and giving the ears an extremely unattractive appearance. After much study of the insect's habits and experiments with various methods of control, Dr. George W. Barber finally developed a barrier method which prevents the worms from entering the ears. He found that the injection of about ¼ teaspoonful of refined mineral oil into the silk mass at the tip of the ear creates an effective barrier against the entrance of the little newly-hatched worms, emerging from the minute eggs laid by the parent moths on the silks, and their subsequent injury to the silk mass and the kernels. Barber also discovered, however, that the oil interferes with the pollination and filling out of the kernels if injected too soon after the appearance of the silks; hence it is necessary to wait 3 or 4 days until the wilting of the silks indicates that pollination is complete. He observed that during this interval some worms succeeded in penetrating well down into the ear tip, and realized the need of some improvement of the method. Further work revealed the fact that a very small percentage of pyrethrum extract or dichloroethyl ether added to the oil killed most of the worms that had entered the ears before treatment as well as those that entered them afterwards. In the course of his studies Barber also devised simple adaptations of common equipment to the application of the oil easily and economically (pl. 17). This method has also been used with some success for the prevention of earworm injury to the highly valuable plantings of pedigreed lines of corn now grown for the production of the high-yielding hybrid field and sweet corns that have almost entirely supplanted the open-pollinated varieties.

Before a successful poison bait for the Mormon cricket was discovered galvanized sheet-iron barriers were widely used in the control of this insect (pl. 11). Long strips 10 inches wide were fastened upright and end-to-end by means of small stakes, across the path of the migrating bands of crickets. Trap pits, or enclosures made of the galvanized-iron strips, were located at frequent intervals along the barrier. In these the crickets gathered and died. Many

miles of this barrier were installed to good effect during cricket outbreaks, but this method has now been almost entirely superseded by the much cheaper and less laborious poison-baiting method of control.

Metal barriers of the type just described have been and are still very extensively used in Argentina against the great hordes of grasshoppers prevalent in some parts of that country.

Another expedient frequently used against Mormon crickets where circumstances permit is the oil-on-water barrier. The crickets do not hesitate to plunge in and swim across streams or irrigation ditches that they may encounter in their migrations. Advantage is taken of this fact to turn strategically located watercourses into barriers by coating the surface of the water with oil. Barrels of cheap, light oil are placed at intervals of about ½ mile along the streams and canals and their contents allowed to drip or dribble slowly so as to form a thin film on the water. This coats the swimming crickets and kills them.

SPRAYS AND DUSTS

Often the first question asked when an insect infestation is discovered on any crop is "What can I spray it with?" Unfortunately, the acre value of cereal crops is ordinarily too low to permit the direct use of insecticides on them. As has already been mentioned, control measures for the insects attacking these crops must be largely cultural or, if insecticidal, must be of extremely low cost as in the case of poison bait, which costs only about 20 to 50 cents per acre. It is true that insecticides are recommended for the direct control of the European corn borer in market sweet corn, but this is a specialized crop which cannot properly be considered a cereal. Because of the rapid growth of the corn and the fact that the egg-laying and hatching period of the borers extends over a month or more, several applications of a spray or dust are required for effective control. This method is too expensive for practical use on field corn, or even on sweet corn grown for the cannery. It is possible, however, that future developments may reduce costs to the point where insecticides may be used profitably against the borer, at least on canning corn.

FUMIGATION

Insects continue to take their toll of our cereal crops even after they have been safely harvested and stored. As has already been noted, they destroy annually some 300 million dollars worth or more of stored grains and cereal products. With the wartime need of conserving our supplies of these most essential foods, the prevention or reduction of such enormous losses becomes extremely important, and at the same time more difficult owing to the interference with normal distribution

and consumption. During the first World War and during the present one special efforts have been made to find ways and means of meeting the situation.

Of several hundred species of insects found associated with stored grains or grain products some 50 or more kinds of moths, weevils, and beetles are seriously injurious when conditions are favorable to their activity. The larvae of some species bore into and mature inside of the kernels, while both the larvae and adults of others are free-living among the kernels or in milled cereal or flour (pl. 19). The larvae of some of the moths not only eat these products but spin silk as they move about, sometimes forming a thick webbing on the surface or within the outer layer. High temperatures and ample moisture are favorable to the development of all these insects. Hence they are a constant source of annoyance and loss in warm-temperate and tropical regions. They are cosmopolitan in distribution, however, and in warm, moist seasons or under suitable conditions such as prevail in flour or cereal mills, they become serious pests in the more northern latitudes as well. When an infestation is once started in stored grain, enough heat and moisture are often generated by the insects themselves to provide for their continued activity and to cause injury to the grain. Some species begin their attack on the grain in the field before it is stored and are carried with it into the bins, warehouses, elevators, and mills. Others live and breed chiefly within these storage places. Most of the species are active fliers in the adult beetle or moth stage and spread locally by flight, but the principal means of dispersion is the commercial shipment of grains and cereal products. They have been carried all over the world in this way.

The first essentials for the protection of stored grains and cereal products are good storage facilities and sanitation. Tightly constructed bins, warehouses, and mills that can readily be kept clean and that will prevent the escape of fumigants when it becomes necessary to use them are basic to satisfactory application of insect-control measures. These insects breed in undisturbed accumulations of grain or floury residues wherever they are allowed to occur, such as in floor cracks, behind lining boards, in supplies of stock or chicken feeds, in used feed or flour sacks, in conveyor machinery, and in household cupboards. Such accumulations serve as sources from which infestations spread to stored grain, cereals, or flour, and obviously should be eliminated.

Owing to the more or less frequent or constant introduction of new infestations in one way or another, however, the periodical application of more drastic measures becomes necessary. The most generally useful treatment is fumigation. Several different fumigants are in common use and the best one to select depends on the circumstances. The so-called heavier-than-air gases, especially ethylene dichloride or

carbon disulphide mixed with carbon tetrachloride to make them noninflammable, are most generally used on stored grains (pl. 18). These are liquids at ordinary temperature and when sprayed on the surface of the grain immediately evaporate to form heavy gases which quickly sink down through it. Another material often used for grain fumigation is calcium cyanide in granular or powder form (pl. 18). This is run into the grain stream as it enters the bin where it quickly reacts with atmospheric moisture to form deadly hydrocyanic acid gas.

The fumigants most commonly used in mill and warehouse fumigation are liquid hydrocyanic acid, methyl bromide, chloropicrin, and a mixture of ethylene oxide and carbon dioxide. These must be liberated by suitable means and in sufficient quantity to obtain an insect-killing concentration throughout the entire building. Chloropicrin, by the way, is the tear gas introduced during the first World War. All these gases are extremely poisonous to humans as well as insects and should be handled only by experienced persons equipped with gas masks adapted to the particular fumigant to be applied.

The ready susceptibility of most stored-product insects to heat and cold is often utilized instead of fumigation for their control. Some cereal products are run through steam or electrical heating appliances to kill any insects they may contain and fair control is sometimes obtained by heating entire buildings to 125° F. or more in hot weather when these temperatures can be produced without too great expense. In the more northern latitudes advantage is often taken of zero and subzero temperatures to eradicate insect infestations in mills and warehouses by turning off all heat and opening the buildings to the outside air. The low winter temperatures and short cool summers of northern climates ordinarily serve to hold insect infestations in grains or cereals in unheated storage to such a low level as to make fumigation unnecessary.

The preemption of carbon disulphide and fumigants containing chlorine for use in various war industries has made them unavailable at times for the treatment of stored grains, and has increased the need of finding available substitutes. Efforts are now being made in this direction.

INSECT-RESISTANT VARIETIES OF CROPS

Although it has been known for many years that some varieties of the different cereal crops are less susceptible than others to their respective insect enemies, deliberate efforts to find and breed this character into improved varieties are comparatively recent developments. As in the case of other ventures into new fields, these efforts were considered by some investigators to be very unlikely to yield results of practical value. Nevertheless, they have been continued and have become extremely promising. Wheats highly resistant to the

hessian fly (pl. 2); varieties of corn resistant to the European corn borer, earworm, chinch bug (pl. 12), or corn leaf aphid; sorghums resistant to the chinch bug; and barleys, oats, and wheats resistant to the chinch bug or to the green bug, have all been discovered through systematic tests conducted in recent years. Breeding operations have also shown that by controlled crossing and selection many of these insect-resistant qualities can be bred into other varieties more suitable for commercial production, and that these qualities are not linked with undesirable characters or incompatible with other desirable ones such as high yield, quality, and disease resistance. Commercially satisfactory varieties or lines of wheat, oats, barley, and corn resistant to one or more of the insects just mentioned have already been produced or, through the application of modern methods of plant breeding, are well advanced toward commercial availability.

Insect control through the use of resistant varieties would have several advantages over other methods of control. Once the seed of such varieties becomes available in quantity and comes into general use the farmers will be automatically relieved of the expense and trouble of applying other control methods. More latitude in cultural procedures, time of planting, and crop rotations would be gained. The frequent, severe, and general outbreaks of certain species that confine their attack to only one or two kinds of grain crops might even be prevented. The development of cereal crop varieties resistant to insects has now progressed far enough to warrant the definite expectation of extremely valuable results in this field.

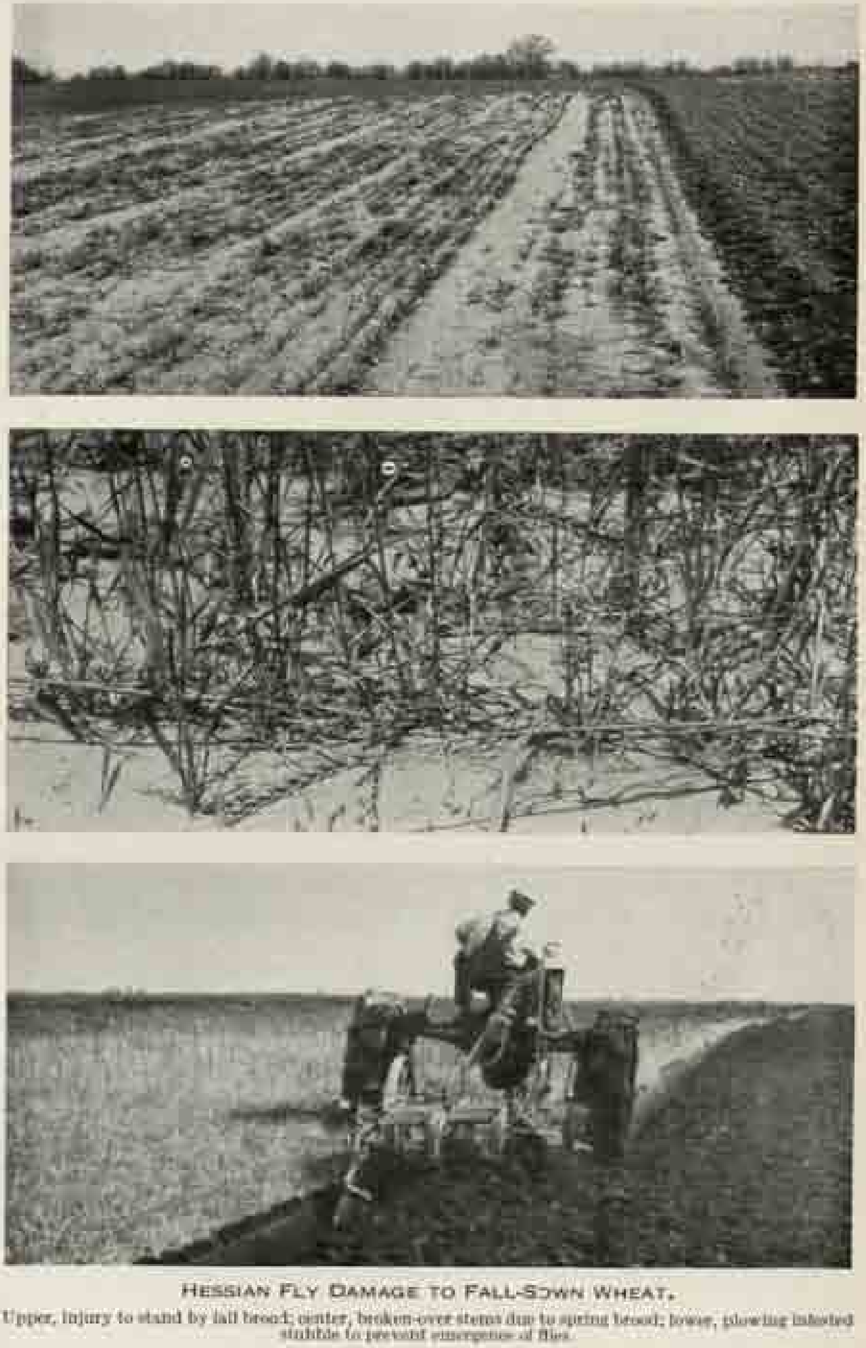
BIOLOGICAL CONTROL

Several writers have called attention to the incessant contest between the insects and man for supremacy. The insects probably would have won long ago if it were not for the natural agencies that hold them in check and for the fact that most of the noxious species are much less readily adaptable than man to variations in environment. Many of those that attack cereal crops, such as the corn rootworm, corn leaf aphid, and wheat jointworm, can breed successfully only on one or a very few species of host plants. Others, such as the grasshoppers, chinch bug, hessian fly, and green bug, although extremely prolific, are highly susceptible to unfavorable weather conditions at certain times in their life history and often suffer violent reductions in numbers as a result. Still others, armyworms and cutworms for example, have many parasitic and predaceous insect enemies that at times almost completely exterminate them in localities where they occur in outbreak numbers. Some cereal insect pests, armyworms, chinch bugs, and grasshoppers for instance, are also subject to bacterial and fungous diseases that occasionally become epidemic under favor-

able conditions. The interactions among these pests, their insect enemies, their diseases, and the weather, are extremely complex.

Since we have not yet learned to control the weather, which is the dominant element in this combination, we are not able to manipulate these factors to any material extent in the prevention of insect outbreaks. In fact, some of our grain-production practices have been more favorable then detrimental to such outbreaks. For example, the planting of large acreages of both corn and small grains in the same neighborhood encourages the multiplication of the chinch bug, as already cited. Another example is the favorable condition for grasshoppers brought about, partially at least, by the extensive growing of wheat during the first World War. With the urgent demand for that grain, great areas of virgin sod on the western plains were plowed and sown to wheat. Although much of this land was gradually abandoned as the demand for wheat subsided, both the wheat stubble and the abandoned land have provided extremely favorable food and egg-laying conditions for the migratory grasshopper, and have been important factors in the persistence and severity of the widespread and almost continuous grasshopper outbreaks in the Great Plains during the past decade. Fortunately, it has been possible to prevent a large portion of the potential crop damage through the application, at great expense, of the baiting method already described, but the problem of working out and applying methods of preventing the outbreaks themselves still remains. This problem can undoubtedly be solved, possibly through the use of some of the slower airplanes for spreading poison bait, when they become available for other than war purposes.

Many of the insect pests of cereal crops, like most of the crops themselves, are not native to this country. Others have adopted these crops as food when they have become widely grown in this country. Notable examples of foreign invaders are the hessian fly, European corn borer, and most of the insects that attack our stored grains and cereal products. The armyworm, chinch bug, and green bug might be mentioned as conspicuous among native insects that have taken readily to imported crops. In cases where the parasite enemies of the invaders did not come along with them efforts have been made to import and establish these parasites. Some of these have become well established while others apparently have not found conditions in this country at all to their liking. In general, it may be said that although the parasites of insects attacking cereal crops are highly beneficial, in no case can they be depended on to keep these pests under permanent control. Other means must therefore be found and applied when necessary if the cereal crops are to be successfully and profitably grown, stored, milled, and supplied to the human rather than the insect population for consumption.

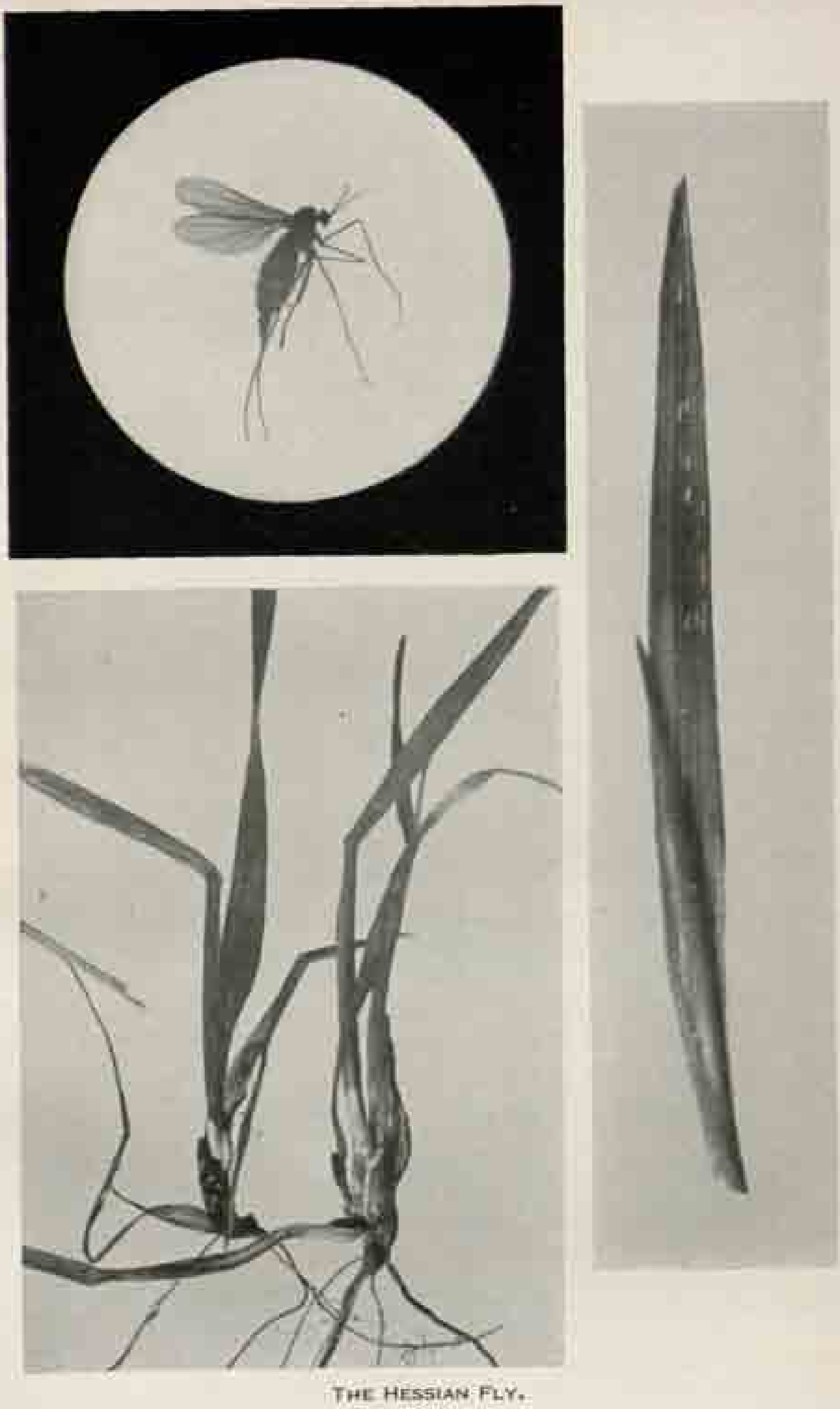


HESSIAN FLY DAMAGE TO FALL-SOWN WHEAT.

Upper, injury to stand by fall brood; center, broken-over stems due to spring brood; lower, plowing infested stubble to prevent emergence of flies.

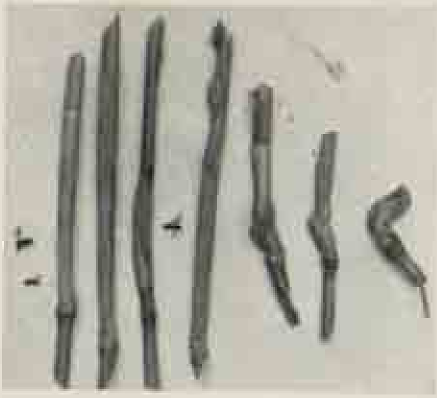
HESSIAN FLY CONTROL MEASURES.

Upper, wheat sown after safe date (center) escaped fall infestation; that sown earlier (right and left) severely injured; lower, variety test, showing difference between resistant and susceptible varieties in stand and growth.



THE HESSIAN FLY.

Left: Upper, adult female, × 4; lower, leaf sheaths stripped away from stems of young wheat plants to show larvae and puparia, natural size. Right, eggs on wheat leaf, × 4½.



DAMAGE BY JOINTWORM AND ROOTWORM.

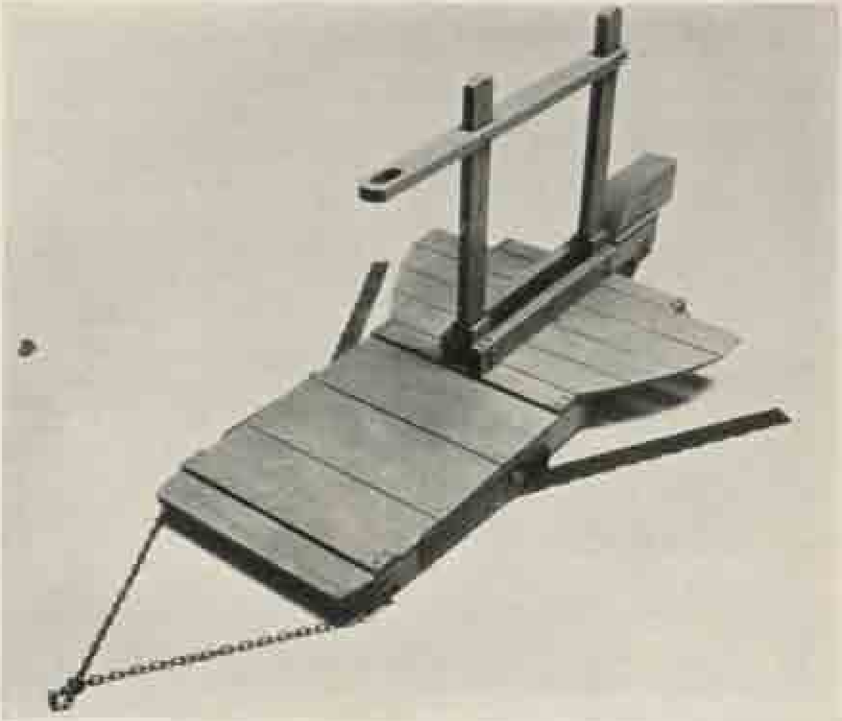
Upper, galls on wheat stems caused by jointworm; center, this corn fell down because rootworm gnawed off roots; lower, wilted bud of young corn caused by rootworm.

EUROPEAN CORN BORER.

Upper, ruined corn plants, stems sectioned to show borings; lower, plowing under infested stalks.

EUROPEAN CORN BORER.

Upper, 311 borers from one hill of corn; lower, cornfield ruined by borer.



SLED HARVESTER FOR LOW CUTTING OF CORN INFESTED WITH EUROPEAN CORN BORER.

Upper, close-up to show construction; lower, harvester in use.

CROP DAMAGE CAUSED BY GRASSHOPPERS.

Upper: Left, grasshoppers resting among stripped wheat stems; right, adult laying eggs in soil. *Lower*, corn ruined by grasshoppers (left), kafir corn not attacked (right).

MIXING GRASSHOPPER BAIT.

Upper, with power equipment; lower, by hand.

SPREADING GRASSHOPPER BAIT.

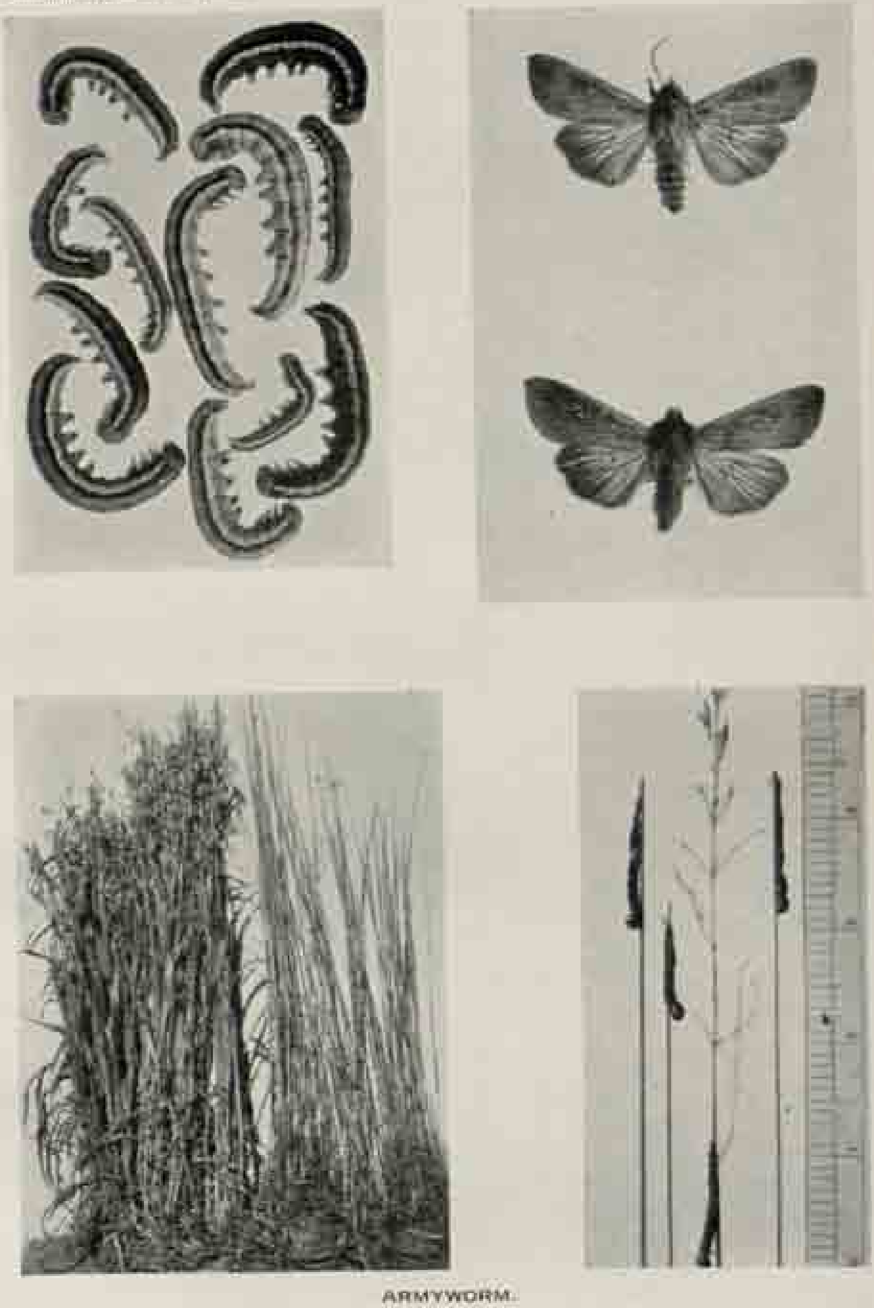
Upper, loading trailer-spreader. Lower: Left, trailer spreaders in operation; right, airplane spreading bait.

MORMON CRICKET.

Upper: Left, sheet-iron barrier and trap; right, adult female, about natural size. Lower, crickets killed by sodium arsenite dust.

CHINCH BUG.

Left: Upper, creosote-paper barrier, corn to left killed by bugs coming from wheat field across the road; lower, susceptible corn (center), resistant corn (left and right). Right, bugs clustered on corn stalk, about natural size.

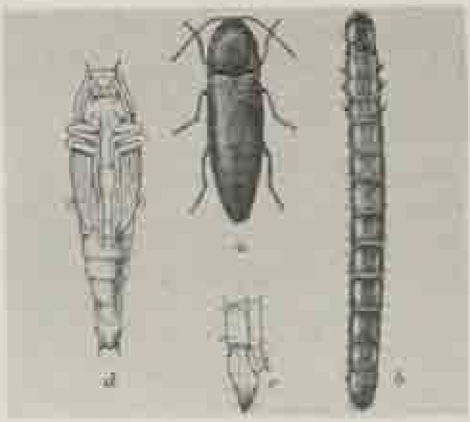


ARMYWORM.

Upper: Left, larvae, about natural size; right, moths, about natural size. Lower: Left, oats stripped by armyworms (right), oats uninjured (left); right, larvae killed by wilt disease.

WHITE GRUBS.

Upper: Left, injury to stand of corn; right, adult (May beetle), about natural size (upper), larva or grub, about natural size (lower). Lower, hickory foliage stripped by adults.

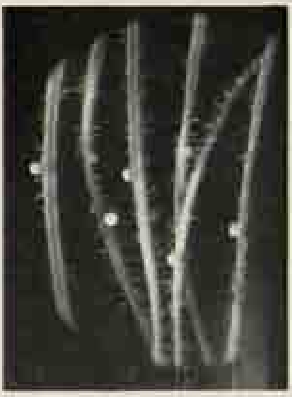


WIREWORMS.

Upper, a, adult (click beetle); b, larva; c, caudal end of larva, side view; d, pupa, all somewhat enlarged. Lower, larvae boring into bases of wheat plants, natural size.

CORN EARWORM.

Left, larvae burrowing in young corn tassels; right, larvae feeding on kernels.

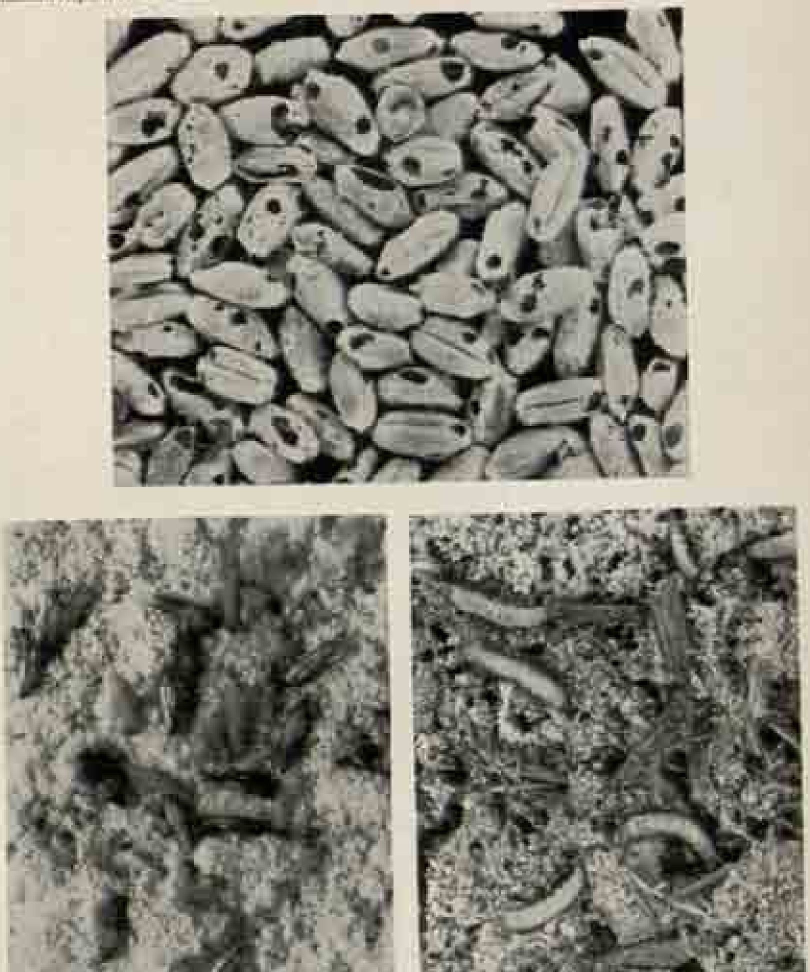


CORN EARWORM.

Upper: Left, eggs on corn silks, greatly enlarged; right, adult moth, about natural size. Lower, apparatus for injecting oil-pyrethrin insecticide into silk mass at tip of ear.

APPLYING GRAIN FUMIGANTS.

Left, apparatus for running calcium cyanide into grain stream entering top of storage bin; right, spraying fumigant on surface of grain stored in steel bin.



STORED GRAIN AND CEREAL INSECTS.

Upper, wheat damaged by rice weevil. Lower: Left, Indian meal moth larvae and adults in corn meal; right, Mediterranean flour moth larvae and adults in flour.

THE GEOGRAPHICAL ASPECTS OF MALARIA [1]

By Sir Malcolm Watson
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Had you asked me 50 years ago to address you on the "Geographical Aspects of Malaria," I should have begun by quoting from Hirsch's monumental work on "Geographical and Historical Pathology" (1883) as follows:

> Covering a broad zone on both sides of the Equator the malarial diseases reach their maximum of frequency in tropical and subtropical regions. They continue to be endemic for some distance into the temperate zone, with diminishing severity and frequency towards the higher latitudes; in epidemic form they not infrequently appear yet in other regions; and, in still wider diffusion with the character of a pandemic, also beyond these indigenous latitudes.

Hirsch follows this with pages describing the various countries throughout the world in which the disease occurs, and an equally extensive discussion of the conditions which influence the appearance of the disease, and of its possible cause. But the discussions lead to no final conclusions; and in the words of Duncan, writing in 1888: "As Crudeli points out, malaria exists on soils of every conceivable variety, of every age in geological time, and it is impossible to point to any mineralogical or chemical conditions which can be said to be essential."

By his discovery in 1880 that malaria is caused by a living parasite, visible under the microscope, Laveran, a French Army surgeon working in Algiers, made an important addition to our knowledge. Malaria then ceased to be "a miasma," a word indicating some sort of emanation from the soil; the word was not exactly defined; and, as we have read, any sort of soil appeared capable of giving out the emanation. Then came the problem. How does this parasite circulating freely in man's blood pass from one victim to another? The genius of Sir Patrick Manson, who had carried out original work in China on another parasite circulating in the blood, provided a hypothesis, which if not wholly correct provided Sir Ronald Ross with a valuable starting point for his researches in India. Manson also gave Ross the most generous and selfless help in other ways.

[1] Address delivered at meeting of The Royal Geographical Society, London, February 9, 1942. Reprinted by permission from The Geographical Journal, vol. 99, No. 4, April 1942.

In a letter dated July 5, 1897, to Sir Charles Crosthwaite, asking him to influence the Government of India to put Ross on special malaria research, Sir Patrick Manson wrote:

> Money can build institutes, but a thousand institutes are useless if they are not manned by the right men. A good man is worth them all. I have no hesitation in saying that at the present moment Ross is the best man in India to carry on malaria investigation. To lose him therefore as I say, would be a public calamity. . . . It would be a vast pity if the chance which now presents of making a substantial addition to the pathological science should once again be lost to Englishmen. We are cutting a sorry figure alongside other nations at present. To our national shame, be it said that few, very few, of the wonderful advances in the science of the healing art which have signalized recent years, have been made by our countrymen. This is particularly apparent in the matter of tropical diseases, in which we should in virtue of our exceptional opportunities be *facile princeps*. . . . But in this matter of malaria here is a chance for an Englishman to rehabilitate our national character and to point out to the rest of the world how to deal with the most important disease in the world—malaria. (Manson-Bahr and Alcock, 1927.)

Infinite patience and the burning energy of his genius enabled Ross to overcome innumerable difficulties, and prove to the world something that neither he nor Manson quite expected: the malaria parasite was not just sucked up by the mosquito from a man suffering from the disease, or transferred mechanically. The parasite actually bred in the wall of the mosquito's stomach; the offspring of the original parasites when mature were injected into another man; so the disease spread. Ross discovered what the parasite looked like in all its various stages in the mosquito and where these stages were to be found; the prolonged researches also proved that not every mosquito could be infected; only some with spots on their wings, later identified by entomologists as *Anopheles* mosquitoes. The mosquitoes which could not be infected are those popularly called *Culex*. This was a huge step forward; indeed it constituted one of the major discoveries of medicine. For malaria probably kills more people than any single disease in the world. The stage was now set for the prevention of malaria by striking at the mosquito.

The medical profession in this connection divided into two camps: in one Ronald Ross; in the other the rest of the profession. Ross realized more fully than did his colleagues at that time the line that would have to be taken if malaria was to be prevented. In an exceedingly able report to the Government of India he wrote that while it was not possible to kill mosquitoes everywhere, it would be wise to make a beginning by ascertaining which of the mosquitoes carried malaria and which did not. Neither Ross nor anyone else working at the problem realized that before this could be successful on a large scale and especially in rural areas, many more years of research would be required with Ross's discovery as its starting point. Nor did anyone realize at first that the very technique which Ross invented

was to mislead rather than guide. For the truth is that only a few anopheles carry malaria in nature, although all anopheles can be infected in a laboratory; which made the prevention of malaria appear to be much more difficult than it eventually proved to be.

This paper must describe just what mosquitoes carry malaria in the main geographical areas, something of the very different conditions in which they live, and the strange ways we have invented to control or destroy them. The story begins in Malaya. After seeing Malaya in 1926, Ross told the Committee of the Ross Institute that the antimalarial work done there was the greatest sanitary achievement ever accomplished in the British Empire, as it was also the first successful antimalarial work carried out in the British Empire, if not in the world. (Ann. Rep. Ross Inst., 1927.)

The Malay Peninsula consists mainly of ranges of granite mountains, and coastal plains with fresh-water swamps fringed by mangrove with salt and brackish water; all three are covered by great forests. Man lives there always at war with the jungle.

It was my privilege to live in the Peninsula from 1900 to 1928, to take an active part in research, and initiate the practical work for the control of malaria (Watson, 1903). In the part of the mangrove forest zone covered by every tide, no dangerous anopheles live and there is no malaria; but in the inner part, covered only by spring tides, *Anopheles umbrosus* breeds and carries malaria. If the mangrove forest be felled, another anopheles appears and this newcomer also carries malaria; today it is called *A. sundaicus.* Both mosquitoes disappear when the swamp is embanked and drained. In 1901 Port Swettenham was saved from closure by embanking, draining, and oiling of pools, and a very complete organization for the medical care of the people. The order to close it had actually been given by the Governor, Sir Frank Swettenham, 2½ months after it was opened, but was not carried into effect when all the facts were put before him by me.

The coastal plains—great swamps deeper and wider than anything in Italy—harbor *A. umbrosus* and are intensely malarial. Here drainage, and selection of sites of houses half a mile from the undrained jungle, gives 100 percent protection against malaria.

Attention was next turned to the hills where it was not possible to get rid of the mosquito by the simple method of drainage. The coastal hills are, when under forest, intensely malarial, because *A. umbrosus* lives in the valleys, while the inland hills are healthy under forest, because *A. umbrosus* does not live there. Both kinds of hill land are intensely malarial when the forest is felled, because yet a third mosquito appears in the picture: *A. maculatus.* It lives in sunshine, and in even the steepest mountain streams, but not where the streams are covered by jungle. This insect causes intense

malaria although there may not be a swamp within miles. In Malaya yearly death rates of 300 per 1,000 were not uncommon among labor forces on estates or on engineering works before effective means to control mosquitoes were devised.

Among the important discoveries in Malaya were the following:

Only 3 out of some 30 species of anopheles in Malaya carry malaria. We had to kill only the dangerous species to stamp out the disease; the others could be ignored. This is called "species sanitation" (Watson, 1911).

Many dangerous-looking swamps, including rice fields on the coastal plains, were not malarial (Watson, 1911).

In 1914 I prepared a mixture of mineral oils which rapidly killed all anopheles in even fast-running streams, but was not poisonous to men or animals. This solved a difficult problem, the intense malaria produced by stream-breeding anopheles. By means of this mixture malaria was rapidly brought under control over large areas, including rubber estates, at practically no capital cost.

In 1909 I realized that Nature controlled species of anopheles in several ways, and that by imitating her we could control malaria at little or no expense in many places (Strickland, 1915; Williamson, 1933). This was sometimes unconsciously achieved by the planters when they opened up the estates. Four years' research on estates showed that the change of species that occurred from time to time was due to changes in the conditions in the valleys. When under jungle there was one species (*A. umbrosus*) that carried malaria; when the jungle was felled and the streams freed from grass, a new species appeared (*A. maculatus*) which also carried malaria; in intermediate conditions of the stream there were half a dozen species that did not carry malaria. The knowledge of how to change species was a notable advance and is today the foundation of a great deal of antimalarial precautions taken in so many parts of the world. Our researches also enabled us to know where to house the people, and thus deaths were reduced to 4.9 per 1,000.

Another method devised as a result of later researches was intermittent sluicing which has a devastating effect even on mosquitoes that live in running water. Devised in Malaya, and capable of being operated by the Malay peasant, this method spread to southern India. Today in some of the bigger streams in the Himalayas there are batteries of sluices. (Williamson, 1933.)

The researches and many inventions for the control of malaria in Malaya carried out by the Government and the rubber planters have thrown a flood of light on the disease in other geographical regions. So I have spoken of it in some detail. Of the work done in Malaya, Professor Swellengrebel wrote in 1935: "The principle forming the base of malaria control in Malaya ought to be the principle under-

lying malaria control in any country in the world. That principle of malaria control is Malaya's great gift to the world." And in 1938 he wrote: "Without species sanitation one feels helpless."

In 1911 I was invited to organize the control of malaria in Singapore. The disease was present not only throughout the year, but it caused a great annual wave with its peak in the month of May. Between 2,000 and 3,000 people died each year as a result of malaria, out of a population of 250,000. Today the population is treble that figure. Yet in 1939 the President of the Municipality could say: "Malaria has been absolutely stamped out. It would be a very unfortunate resident who contracted malaria now." It has been calculated that all health measures, of which the most important by far has been the prevention of malaria, have saved over 100,000 lives in Singapore in the last 30 years.

Of the value of the combination of research and practical work to the community, I may quote from an address by Eric Macfadyen (1938):

> Had it not been for malaria control, British Malaya . . . could never have been realized. Its populous towns, its railways and roads which have unlocked its natural resources, the monster dredging plants, representing an outlay of millions sterling, which excavate its tin, its 300,000 acres of rubber . . . not a tithe of these developments could have been achieved had malaria remained uncontrolled. . . . The most recent and most sensational triumph of the application of these principles has been the construction of the Singapore Naval Base. Without malaria control this great work must have cost countless lives, if indeed it could have been completed at all. To the great credit of the military authorities the health problem has been handled with such success that the lay world has not known there was one, and those great works have been carried out virtually without affecting the vital statistics of Singapore.

In 1913 I crossed the Straits of Malacca to Sumatra, to meet Professor Swellengrebel, who was to play a most important part in the conquest of malaria. In Sumatra, less than 100 miles from Singapore, I found to my astonishment a totally different malarial picture; for the disease was confined almost entirely to the mangrove forest zone, with *A. sundaicus* as the enemy. Hill streams, which would have been so dangerous in the Malay Peninsula, were harmless in Sumatra. In Java the picture is practically the same, although in both there are occasional outbreaks of disease away from the coast, the cause of which although interesting would take too long to explain.

Sumatra is much less populated or cultivated than Java. Indeed Java is an almost continuous sheet of wet rice, of which it would probably be true to say that over 95 percent is free from malaria. Sumatra and Java both differ in yet another way from Malaya. They are volcanic islands, belonging to the great volcanic chain fringing South and East Asia, including also the Celebes, the Philippines, Formosa, and Japan.

In British North Borneo, researches, not yet completed and not yet published, by Dr. John McArthur, whom I am proud to claim as a pupil, indicate that the dangerous anopheles of Malaya may not be carrying the disease. *A. leucosphyrus*, a mosquito that lives at the headwaters of streams in dense jungle, has been proved to be the important carrier in an intensely malarial area. It may be that merely clearing the undergrowth, and allowing cattle to keep the undergrowth down, will eliminate the disease, at little cost to the poor and half-starved inhabitants.

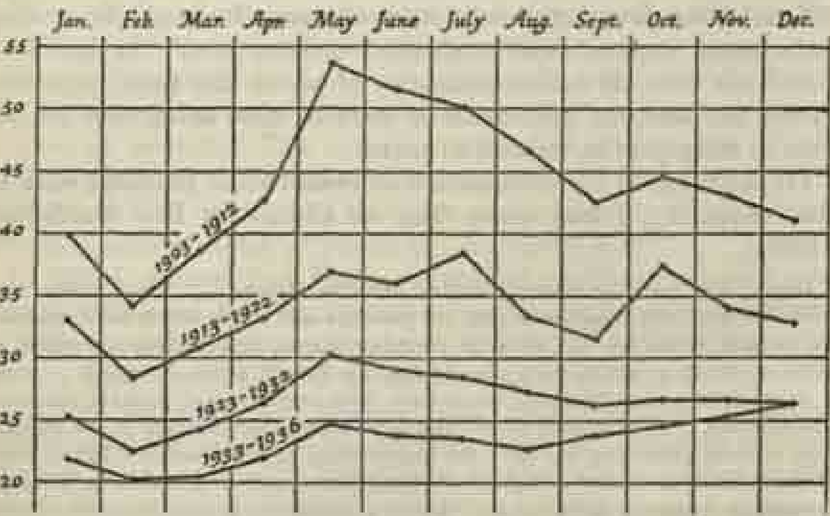

FIGURE 1.—Mean monthly death rate in Singapore from all causes.

In the Philippine Islands the picture changes again. Here, as in the coastal plains of the Malay Peninsula, Java and Borneo, Siam and Burma, the rice fields are healthy. In the Philippine Islands the mangrove zone is also healthy, unlike Java and Sumatra. But along the foothills *A. minimus* breeds among grass in slowly moving clear water and produces intense malaria. This mosquito is one of the great carriers of malaria, for it carries the disease not merely in the Philippine Islands, but extensively in the continent of Asia: in French Indo-China, in Siam, on the Burma Road, and not least in the great Assam Valley of northern India. To it is due the deadly Terai malaria and blackwater fever in the area along the foothills of the eastern half of the Himalayas in India. The brilliant researches of G. C. Ramsay, Deputy Director of the Ross Institute (1936), have proved this. His equally brilliant prevention of the disease is not sufficiently known. It is sheer white magic to wipe deadly malaria from a valley by growing a hedge of wild rhododendron or wild privet over a little stream, without interfering with the growth of the rice in the more stagnant

waters of the valley. Today there are some 5,000 miles of these hedges in India.

There are in India some 40 species of anopheles, only a few of which carry malaria. *A. philippinensis* causes devastating malaria in Bengal in areas protected from river floods by embankments, but is impotent where the land is submerged each year by floods. The devastation and depopulation resulting from man's efforts to control the rivers must be seen to be believed: hundreds of thousands of acres in jungle and a million lives lost. In the Punjab *A. culicifacies* produces great epidemics. Fortunately the last bad one was in 1908.

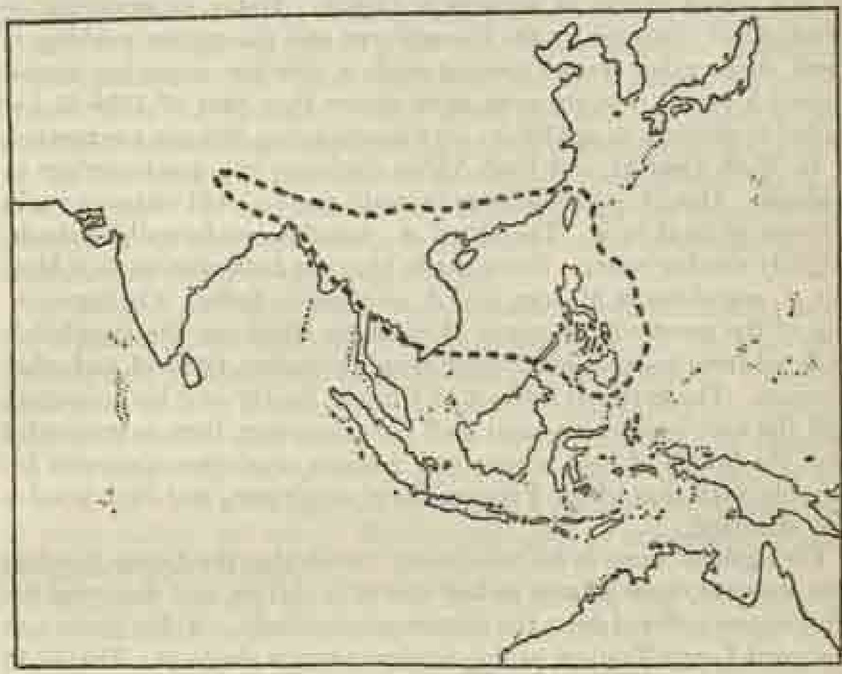

FIGURE 2.—Area where *A. minimus* is harmful in the foothills.

Of the great work in improving the health of their laborers and European staffs carried out on tea, rubber, jute, and the mining industries in India a brief but interesting account will be found in the last Annual Report of Committee of Control of the India Branch of the Ross Institute (Calcutta, July 1941). Extensive work in the prevention of malaria is now being carried out by the Imperial and Provincial Governments in India, both in towns and villages; I know of no country which in the last decade has done more brilliant scientific and practical work in preventing malaria than India.

Before leaving Asia for Africa we might just glance at malaria in Ceylon. There was once a great civilization in Ceylon, which was destroyed by war some 800 years ago. The Indians came to the island

and drove the inhabitants, not for the first time, away from their culture, their ricefields, their lovely architecture, and their carving. Anopheles killed the people whenever they returned and tried to recolonize those areas. In Ceylon there are many monuments, but the greatest is the ancient irrigation system. In every river there are a large number of dams holding up the water; that is necessary because it is not unusual for there to be less than 20 inches of rain a year over two-thirds of Ceylon. In 1934–35 an epidemic of malaria killed over 80,000 people in a few months. The cause was a drought; absence of the flushing of the rivers allowed *A. culicifacies* to breed in profusion. It is a potent carrier of malaria in Ceylon. Today an organization created and operated by the Government and the estates working in close cooperation would prevent such a disaster occurring again; indeed a recent drought even more severe than that of 1934–35 has failed to produce an epidemic: very encouraging, but not unexpected.

In West, Central, and East Africa there are two great carriers of malaria. One, *A. gambiae*, lives in sunlit pools of still water; a water current is fatal to it. The other, *A. funestus*, prefers slight shade, slightly moving water. Dense shade blots out both species, as it blots out *A. maculatus* in Malaya, and *A. minimus* in India. On the opening of the great copper mines of northern Rhodesia, the population suffered from malaria, blackwater fever, dysentery, typhoid, and other diseases. The personal interest of Chester Beatty and his colleagues and the exertions of the local staff have, however, been so successful that the health of both whites and African employees compares favorably with that of the Panama Canal employees, and that is not a low standard.

Livingstone wrote in his missionary travels that the Lower Zambezi was the most malarial area he had visited in Africa, and that even the Portuguese suffered from the disease very severely. A few years ago the great Lower Zambezi bridge was built across the river. Thanks to the advice given by the Ross Institute through C. R. Harrison, a member of the staff of the Ross Institute, the work was carried out with a minimum of sickness. Actually only one European out of seven went down with malaria. (The Times, October 31, 1934; Dixon, 1935.)

There is some reason to hope that researches carried out by the Ross Institute on mines in West Africa will open a new chapter in that area. Unfortunately malaria is widely spread through Africa, reaching south to Durban, and north into the oases of Egypt, Libya, Algiers, and Morocco. In the equatorial belt it is intense; it rises even into the highlands of Kenya. Nairobi itself at 6,000 feet above sea level is not free from the disease.

Of Panama, you all know the great triumph of the United States Government, guided by the genius of Surgeon General Gorgas. The French failed because they had not discovered how to control malaria

or yellow fever. Success in Panama and Malaya came because Ross did not throw in his hand in the early days and because Sir Patrick Manson, so to speak, sustained Ross's hand at a critical period. In 1915 the Panama Canal represented the greatest engineering and medical triumph the world had seen. Like so many other great things it was so misunderstood and misrepresented, that it almost became a stumbling block, and the honor of starting antimalarial work in the United States fell to two nonmedical men: Professor Herms and H. F. Gray working in California. They began in 1911. In 1916 the Rockefeller Foundation, after sending two distinguished scientists to study Malayan methods, took up the prevention of malaria in the United States and has given a great lead to that country. In passing I would mention that research and practical work carried out on the reservoirs of the Tennessee Valley Authority have developed a new method of controlling mosquitoes. By raising and lowering the level of the reservoirs a potent method of controlling anopheles has been demonstrated. It acts by stunting vegetation on the edges of the reservoirs. *A. quadrimaculatus* is the main carrier of malaria in the southeastern States of the United States.

Although *A. maculipennis* is to be found throughout Europe from the Baltic to Cape Matapan and from Spain to the Caspian Sea, malaria is to be found mainly in the Mediterranean region. For over 2,000 years malaria defied all man's efforts to reclaim and cultivate the Pontine Marshes. But within the past decade, Mussolini, by destroying the anopheles, has colonized this area; perhaps this will be his greatest, or only, abiding claim to fame. I remind you though that 25 years earlier we had in Malaya managed to accomplish bigger things in bigger swamps.

The Dutch quickly grasped the significance of the researches in Malaya on malaria, and when he returned to Holland from the East Indies, Professor Swellengrebel, with the aid of his colleagues, carried out some brilliant researches. They showed that there were two races (or species) of *A. maculipennis*, one of which bred in brackish water and carried malaria, the other which bred in fresh water and was harmless. This was the prelude to researches in other parts of Europe, which split *A. maculipennis* into six races (or species) only some of which carried malaria. This explained many anomalies.

A couple of hundred years ago malaria was not uncommon in England, in low-lying areas like the Fens or the Thames Estuary. Indeed, London itself was not free. But drainage and reclamation of land have wrought so many changes that when malaria was implanted in England in 1917–18 by the soldiers returning from foreign lands, it died out within 4 years.

During a visit to some of Chester Beatty's mines in Serbia, I took an opportunity of visiting Salonika to see an area in which according

to the official history "malaria dominated the medical and military situation." This medical disaster had come from two anopheles, *A. maculipennis* in the swamps, and *A. superpictus* in the hills, and a failure to control them. *A. superpictus* I had already seen in Albania and south Serbia. It breeds among stones in slowly moving hill streams. Its distribution is extensive. It has been mentioned in Spain and north Italy. But it is the great carrier in Sicily, Dalmatia, Yugoslavia, Albania, Macedonia, Greece, Bulgaria, Thrace, Anatolia, Cyprus, Caucasus, Transcaucasus, Cilicia, Syria, Palestine, Sinai, Upper Mesopotamia, Turkoman Republic (Transcaspia), Cossack Republic (Tashkent), Bokhara, Persia, and northwest India. As we read the names, which I have taken from a book on the anopheles of India (Christophers, 1933), we are reminded of the victorious march of Alexander the Great against the Persian King and on to India. You will remember how, when his army refused to go farther, he sailed down the Indus and up the Persian Gulf, and how he died at Babylon.

> The exploration of the waterways round about the empire was Alexander's immediate concern, the discovery of the presumed connection of the Caspian with the Northern Ocean, the opening of a maritime route from Babylon to Egypt round Arabia. The latter enterprise Alexander designed to conduct in person; under his supervision was prepared in Babylon an immense fleet, a great basin dug out to contain one thousand ships, and the water communications of Babylon taken in hand. (Encyl. Brit., 14th ed., p. 570.)

The excavation of earth and the aggregation of laborers are notorious antecedents of an outbreak of malaria; for the excavations create mosquito-breeding places and the laborers supply the malaria parasites. By then it was the month of June, when malaria, as we found in the last war (Christophers, 1921) is in full blast. So we are not surprised to read:

> At last all was ready; the 20th of the month Daesius (? June 5) was fixed for the king's setting forth. On the 15th and 16th Alexander caroused deep into the night at the house of the favourite Medius. On the 17th he developed fever; for a time he treated it as a momentary impediment to the expedition; on the 27th his speech was gone, and the Macedonian army was suffered to pass, man by man, through his chamber to bid him farewell. On the 28th (June 13) Alexander died. (Encycl. Brit., 14th ed., p. 570.)

The fever may have been typhoid; but it all suggests malaria. Quinine was unknown to the Greeks. If it were malaria, the species that infected and killed the victor of so many fights would probably be, not *A. superpictus*, which is confined to the submontane regions of Mesopotamia, but *A. stephensi*. This is the mosquito which Ross thinks was the one he first infected with malaria in his little laboratory at Secunderabad in India.

Historians are divided about the character of Alexander, and whether this intrusion of Greek arms and philosophy into the culture and religion of the East was all for the best. That I am not competent to discuss. Nor need I speculate on what difference it would have made had fever not cut short the life of this conqueror, and whether he would have become an equally great administrator.

But there is no difference of opinion about the debt mankind owes to Ronald Ross. I have told you something of how our nation has employed Ross's discovery. Much still remains to be done to prevent tropical diseases. There is still much to be discovered about malaria and its prevention. But in scientific research and practical prevention of malaria from 1901 to the present day, the British have given a clear lead to the world.

Though they have not done all, they have done something of what Sir Patrick Manson urged. I think we can justly claim that the British have not been unfaithful to their trust. And if we turn to an impartial witness such as Professor Swellengrebel we have his assurance that the work done in Malaya has been of great benefit to the world; without what has come to be known as "species sanitation" the fight would have been hopeless. So that Malaya, in this time of trial, can feel that she has achieved something of lasting benefit.

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THE BROMELIADS OF BRAZIL

By Mulford B. Foster
Orlando, Fla.

[With 10 plates]

The plant family Bromeliaceae—the pineapple family—comprises some 50 genera with more than 1,600 known species, 400 of them native to the Americas from Panama north, and at least a dozen native to the United States, most of these in Florida. Although these bromeliads, as they are called, are as yet little known in the States, nevertheless until recently it was thought to be the "largest family of plants to be wholly confined in origin to the New World."[1] Now, however, one species of a *Pitcairnia* has been found in Africa. This is the only report of Bromeliaceae native outside the Western Hemisphere.

The most complete and outstanding botanical contribution to the knowledge of this family was the monograph by Mez published in Germany in 1934–35. In this country, work on the Bromeliaceae continues in the able hands of Dr. Lyman B. Smith, of the Gray Herbarium at Harvard, who is now recognized as the foremost authority.

WHERE THE BROMELIADS GROW

The range of the widespread Spanish moss (*Tillandsia usneoides*) marks the outer boundaries of this interesting family, which extends over all the tropical and subtropical areas of the Americas. From southeastern Virginia through Central and South America across the Argentine and from Chile up as far as Baja California, this cosmopolitan group of plants has spread itself.

The wide range of bromeliads gives them versatile growth habits, for they are happy in the desert, by the side of the ocean, in the wettest jungles, in full or part sun, and in complete or partial shade, and they grow on almost anything, including the smooth or rough bark of trees, on rocks, in sand, on cacti, on palms, and even clinging on

[1] Smith, L. B., Geographical evidence on the lines of evolution in the Bromeliaceae. Sonderdr. Bot. Jahrb., Bd. 66, Heft 4, p. 447, 1934.

telephone wires as does *Tillandsia usneoides* and *Tillandsia recurvata*.

Having collected bromeliads in Mexico and Cuba, Mrs. Foster and I found irresistible the opportunity to collect them in the jungles of Brazil, home of the greatest number of bromeliad species. Accordingly we sailed from New York in the spring of 1939, but when we landed 2 weeks later in Brazil, it was fall below the Equator.

While waiting for our permit, we took several short collecting trips near Rio with Dr. Bertha Lutz, botanist, who is making an intensive study of the flora in the Distrito Federal. However, her work is not confined to botany, for she is an eager student of zoology with particular interest in frogs and, with her father, the late Dr. Adolpho Lutz, has made outstanding contributions to the knowledge of frogs in Brazil. While collecting with her, we developed a new interest in bromeliads—that of the fauna, particularly the frogs, that live deep in the centers of the water-filled bromeliads. From that time on we found the study of frogs to be an interesting accompaniment to the collecting of bromeliads.

Our first collecting trip in Brazil was prophetic in that we found our first new species of bromeliads, for we later realized that this set the pattern for our whole Brazilian trip—we were always turning up new species. Our total of over 60 (with more yet to be described) was as much of a surprise to us as to the botanists, especially Dr. Smith, the bromeliad specialist. In the thousands of herbarium sheets from Brazil which he had examined in the past 10 years, only 9 new bromeliads had shown up from that country. While I had hopes of finding a few new species, I did not expect to find very many because this family has been well collected in Brazil, nearly one-third of the known species having been found within its confines.

Our "safari" numbered two. Our equipment was meager: two suitcases, two cameras, a herbarium press, and a gasoline stove. The most important factor, however, in our equipment was our limitless enthusiasm for the fascinating family of Bromeliaceae.

Searching for bromeliads has taught us many lessons in topography, for Brazil is a land of contrasts. It includes extremes of weather and terrain. During two winters of some 12,000 miles of trekking by water, rail, auto, and on foot, the bromeliads took us into almost every kind of condition that that great country has to offer. One day we were in the rainiest jungle of Brazil, at Alto da Serra south of Rio, which is over 1,500 miles south of the Amazon; and next we traveled nearly a thousand miles by coastwise steamer, by narrow-gauge railway, by ox cart, and on foot, through Bahia, where it had not rained in 2 years.

One does not have to travel far after reaching Rio to do a bit of plant collecting. Even within the city limits there are still vast jungles covering the mountainsides high above the inhabited area. These rain

forests of the Serra do Mar, mountains along the sea, stretch for miles both north and south, and there is a wealth of material for the botanist within a comparatively short distance of the coast. It is probably for this reason that the greatest number of bromeliads have been taken from this area within the past half century.

Strangely enough, one of our most pleasant experiences in Brazil was the visit to Alto da Serra, where we could not collect any plants. It is a sanctuary where the balance of life is to be sacredly maintained. Man is not to disturb the plant, animal, or insect life in any way. He may come there and see it unfold before his eyes, but no collecting or molesting is allowed. This is the great plan of the able Dr. F. C. Hoehne, of the Instituto de Botanica at São Paulo, whose sincere desire it is to preserve for posterity a complete rain forest in one of the most unusual situations in the world. Here is Brazil's greatest rainfall. It is at the high edge of the Serra do Mar mountains, which rise abruptly from sea level. The warm rain clouds from over the sea striking this cold mountain barrier produce almost continuous precipitation in the form of either rain or fog. This makes a perfect home for innumerable moisture-loving epiphytes.

A very comfortable guest house had recently been built here for the accommodation of observing scientists, and we were complimented by being the first guests to use it. This was one of our favorite "collecting" spots, where we collected only photographs and many an impression on the mind's eye of the luxuriant fantasies in myriad forms of plant life. Everything was doing its individual bit toward making this one of the natural beauty spots of Brazil.

We were also invited to be the first guests to use Dr. Hoehne's unique creation, a botanical truck. It was a giant Chevrolet, rebuilt so as to have sleeping quarters for six, with ample storage space for supplies, and, best of all, it had a heating "oven" where a huge press of fresh botanical material could be "cooked" until thoroughly dry. In this truck we experienced a truly delightful trip in the land of the decorative Pinheiro do Paraná (*Araucaria brasiliensis*).

Villa Velha should be as well known in Brazil as the Painted Desert or the Bad Lands in North America, but so far few others than naturalists are aware of it. "Old City" it is called, because from a distance it resembles the skyline of an ancient abandoned city. It is a "rock continent in a sea" of vast rolling plains. Mother Nature has for centuries been slowly revealing this marvelous work in sandstone which stands now tranquil, dominant, in a turbulent sea of shifting sands. For miles we had rolled over treeless land to reach this "rock of ages." Only the time-carved monoliths had vegetation. They were covered with Arecastrum palms (*Cocos plumosa*) and Araucarias (the Paraná "pine"), cacti, ferns, orchids, and bromeliads living in every crevice,

hanging on with grim determination as though they would not give up until the rocks themselves disintegrate. Every narrow canyon, dark and damp, harbored bromeliads of the more delicate type, while above, braving wind, sun, cold, and heat, were the xerophytic ones. Villa Velha is a botanist's and geologist's paradise.

THE BROMELIAD CHARACTERISTICS

When you enjoy the sweet, juicy fruit of a pineapple, you are eating a bromeliad, *Ananas comosus* (*sativus*). When you sink into a soft, well-cushioned automobile seat, the filling responsible for your comfort may be a bromeliad, *Tillandsia usneoides*, or Spanish moss. In manner of growth these two represent the two extremes: the pineapple is strictly terrestrial, while the Spanish moss is wholly epiphytic, even going so far as to dispense with roots. Between these two extremes, bromeliads exhibit a great variety of plant characteristics.

It would not be difficult to surmise that these two forms might be the latest development, each in its own type of fruiting method—the appendaged-seed type (represented by the Spanish moss) and the berry-seed type (represented by the pineapple). The pineapple has had all its fruits fused into one big "berry." No other fruit-bearing type in this family has the individual berries that hold the seed more completely welded than in the pineapple fruit. On the other hand, the Spanish moss, with its appendaged seeds in a pod, grows with such a fusion of leaves in one continuous growth that there is no evidence of roots (which, I believe, have been absorbed) or of the usual maturing of individual plants, characteristics which probably make it the latest development in the appendaged-seed division. We might say that this "freak" of a plant is certainly the most modern, for it travels entirely by air.

The bromeliad flower pattern is formed in multiples of three. Its flowers generally are formed in spikes or racemes with brightly colored bracts. In the botanical descriptions of this family every flower has been said to be monoecious or perfect, even though in some of the Hechtias (of Mexico), the flowers of which have both stamens and pistils, only one of them functions.

An exception appeared during January 1942, when I observed that in several of the species of *Cryptanthus* the flowers were not monoecious, but dioecious, for there were separate male and female flowers in the same plant. (One of our *Crypthanthus* species, not yet determined, however, does have all perfect flowers.) This condition of separate sex flowers has apparently not been noted before, as there seems to be no record of it in the literature.

Flowers throughout the family range in size from tiny, almost microscopic blossoms as in the giant *Hohenbergia augusta*, in which the

minute stamens even hide the petals, to the large, lovely blue-violet flowers 2 inches in diameter of the *Tillandsia Lindenii* of Ecuador. Flowers that stay open for several days are the exception, but a stranger exception is the flower of a new and as yet unnamed *Aechmea* I found in Brazil that opens after midnight; 3 hours later the petals close and begin to dissolve into the sweet nectar already formed at the perianth. While each species has its more or less regular blooming period, I have by careful and persistent search found a great number of species blooming out of their "time" for some unknown reason.

Along with the variance in flower sizes goes a peculiar range of odors: the white flower of one of our new species (*Vriesia hamata*) smells like an onion, another (*Vriesia vulpinoides*), like a fox. Some have an exquisitely sweet perfume as in *Tillandsia decomposita*, or the fresh fragrance of a ripening apple as in the unopened buds of the new *Vriesia Racinae*. When this flower opens, the fragrance disappears. The majority of bromeliad flowers, however, have little fragrance. While the flowers, it is agreed, generally produce the odor, in the case of *Aechmea purpureo-rosea* I have found that the entire inflorescence independent of the flowers has a "toilet soap" fragrance for weeks before and after the flowers are open, as well as during the blooming period.

The color of the flowers covers the entire range of the spectrum, but the predominant hue seems to be in the lavender to blue range, although white, yellow, green, and red are frequent. Most of the bromeliads are colorful during the blooming period but not always because of the flowers. Many species have small and inconspicuous flowers, but the colorful red bracts or leaves surrounding them will give the inflorescence the brilliant and dashing display so much admired. In some species as, for example, *Cryptanthopsis navioides*, the entire plant turns scarlet at blooming time, but as soon as the flowers have finished their mission the color of the leaves fades away and it becomes just another green plant.

One of the new Neoregelias that we found holds its blaze of color in the wide cup bracts for months, until after the seeds have matured. But some of the Nidulariums that so colorfully surround their lavender flowers with a rosette of bright red bracts give up that color after the last flower is gone.

The fundamental motif of plant form in this family is a whorl of leaves forming a rosette. In most of the terrestrial bromeliads the rosette form is obvious and resembles to a certain extent the familiar pineapple plant. In many of the epiphytes, of both the rosette and tubular form, the leaves are held so securely above the base that they become most efficient reservoirs and hold rain water constantly. In many of the Tillandsias the rosette form is close and the leaves are

constricted and generally covered with tiny peltate scales which serve as "cups."

In the "style" of leaves there is great diversity in color and form, which makes so many of the bromeliads highly decorative plants even when not in bloom. Spots, horizontal and longitudinal stripes, zigzag mottling and plain green, spiny and perfectly smooth surfaces, are leaf characteristics which, together with a wide range of color from many shades of green and yellow to grays, reds, and maroons, combine to produce the bromeliads' bizarre beauty. Some leaves are coarse and stiff, others are delicately drooping and grasslike. Some leaves are so curled and dried up that they give little appearance of life. The half-inch leaves of *Tillandsia tricholepis* are indeed dwarfs in comparison to the 9-foot leaves of *Streptocalyx floribunda*.

Wide variation in the size of the bromeliad plants is well illustrated even within the genus *Tillandsia* by the tiny 1-inch *Tillandsia loliacea* and the huge *Tillandsia grandis* of Mexico which shoots a branched inflorescence 11 feet high.

Most of the bromeliads have roots, but in many species these no longer function as feeders. The ability to feed through the leaves is particularly emphasized in the epiphytic types. *Tillandsia usneoides* (Spanish moss) and *Tillandsia decomposita* thrive, although entirely lacking in so fundamental a part as roots. *Tillandsia usneoides* seems to have merged the roots with the leaves, both in function and in appearance. *Tillandsia decomposita* of Matto Grosso develops a few roots in infancy and then dispenses with them and matures with the leaves tenaciously curled around the twigs within its octopuslike grasp.

However, most epiphytic types retain enough roots to serve as a brace to hold the plant either in an upright position so as to catch the rainfall or in a downward position (as we found them in high, cold Mexican climates), so as *not* to hold the water which might freeze between the leaves. This method of clinging to trees has been the cause of the mistaken viewpoint that these epiphytes are parasitic. They actually take no substance from the trees to which they cling. They need only a position where they will get adequate aeration and where they will be able to catch the rainfall as well as the falling leaves from trees above, which decompose into a vegetable "tea" in the "cup" of water. This is the food taken in by the leaves, a process that eliminates the age-old plant habit of feeding through the roots. It may be conjectured that at the remote period when the first terrestrial bromeliads were developing, they encountered the choking, dark, overcrowded jungles. For survival they took to the trees, where they lost most of the feeder function of their roots.

Yet it is interesting to see how quickly the hold-fast roots of the epiphytes can be converted to function more as feeder roots. In a greenhouse the roots of a potted bromeliad function as feeders and

become succulent, but when the plant is attached to a tree in the jungle the food comes from above, and the hard and wiry roots are used only for holding fast. Many of the bromeliads are undoubtedly versatile enough to get their food the easiest way, but the more highly epiphytic types have specialized to such an extent and gone so long without root feeders that they simply cannot stand "wet feet" or roots smothered in a heavy soil, for they promptly rot at the base.

Those epiphytic bromeliads which out in the jungle accumulate decayed vegetable matter in the center cups must have rain water to make the food soluble, and those bromeliads which have neither center cups nor feeder roots, such as many Tillandsias, also need rain to help assimilate their food from the dust particles of the air. But in the absence of rain, the dew collected daily in the peltate scales that cover their leaves enables them to live for months without rain, attached to a limb or the perpendicular side of a rock in full sun; thus they are true xerophytes.

Although Tillandsias such as *T. usneoides* and *T. decomposita* will certainly grow profusely without the aid of roots or any visible supply of food, the experiments that I have carried out and seen conducted have convinced me beyond any doubt that most of the bromeliads must have a source of food other than just air and rain. The plants will live for some time without proper nourishment if not exposed to too much sun, but they certainly will not thrive, especially if they are suspended from wires as was done in an experiment in Brazil to prove the theory that they need no food other than air and water. I have seen these plants there. They hang on wires and hooks, hundreds of them, and, yes, they were living—some of them—but they were gasping pitifully for existence and were dying one by one. The only happy ones were the exceptionally few types of Tillandsias that really can "do the impossible." Even pineapple plants were hung on wire, but I assure you that they would never bear fruit. Each plant had literally to live on itself, gradually getting smaller and finally drying up. It was a terrific endurance test and, except for some of the orchids, I know of no other plants that could have held on so long.

In the field I have found isolated examples of "natural misplacement": pineapple plants and plants of *Bromelia serra*, both terrestrial, whose seeds undoubtedly were dropped by birds in the boots of a palm high off the ground. However, these plants were not happy, nor were they bearing fruit, but were gradually growing smaller.

That terrestrial bromeliads also tend to feed through the leaves has been shown by the commercial pineapple growers, who have found that fertilizer thrown into the base of the lower leaves is more readily taken up as nourishment and produces faster growth than when it is distributed only in the soil surrounding the plant. This is an illustration of the tendency of practically the entire family to be able to feed

through the base of their leaves. However, I believe that the more primitive forms such as Puyas, Dyckias, and Encholiriums still feed mostly through their roots.

In trying to grow these interesting plants I have not learned of all the "food" they like, but I have learned certain things they do not like. They cannot tolerate the dripping of water from lime, copper, or galvanized iron. The drip from these will burn the leaves, and any such burn often kills the plant in a short time. Even a small copper wire piercing a leaf will usually kill that leaf. While they have an amazing capability for going without apparent food and withstanding adverse conditions, in other respects they are much more fastidious. Any food given bromeliads must be acid, as alkalinity derived from water or from foreign substances is disastrous to them.

THE EPIPHYTIC RELATIVES

Before going to Brazil our interest in bromeliads was focused on the epiphytic types. From a decorative standpoint and because of their interesting way of life, we found them completely fascinating. The epiphytic types were found in the rain forests all along the coastal areas where it is high and cool at night yet warm during the day, where frequent rains or heavy dew supplied their water. The trees were laden with a dazzling profusion of bromeliads and other epiphytes making unique pattern and design everywhere in the lush jungle.

We expected to find the epiphytes wherever there were moist areas. A ravine, a stream, or a swamp seemed to be the very choicest spot for them. But one of the greatest surprises and disappointments came when we collected in the huge swamp areas of Matto Grosso. We had come by train from eastern Brazil to the far west, where the Rio Paraguay cuts through South America's largest swamp. Up the river we had traveled for miles and had seen countless thousands of trees, but they were barren of bromeliads. Only where there is an elevation will be found trees and rocks that may harbor a few epiphytes. If a similar swamp area occurred near the great jungles on the coast it would be a paradise for the epiphytes, as well as for the collectors who enjoy finding them.

The high plains between the vast swamp area and the jungles of the coast section have been the "Green Hell" barrier that these moisture-loving plants could not cross. A few Tillandsias that disperse by means of wind-blown plumose seeds have flown over those dry areas, and a few drought-resisting tubular types of Billbergias and Aechmeas have also come most of the way. It would be interesting to go back there a few thousand years hence to see what descendants will be developed from some of these pioneers, for certainly the migration

to this, geologically speaking, young territory will produce interesting new species.

In the great primeval forest at the Cacão Experiment Station in Agua Preta, Bahia, we found a lush jungle garden, a plant paradise for eager collectors. Great masses of climbing begonias startled us, Philodendrons of fantastic shapes and design blended in an ornate pattern with Calatheas and Tradescantias of fancy foliage, and ferns crowded every available opening on trees, rocks, and ground. Many areas were almost impossible to walk through. If we were not being tripped by stout cords of lianas, thorny leaves and treacherous small palms were always reminding us of the things on the ground and interfering with our more ethereal aspirations of looking for the epiphytic beauties above us.

There in the "upper strata" we found two huge epiphytes, both new species. These plants, *Aechmea conifera* and *Aechmea depressa*, were giants among epiphytes. The flower head alone of *Aechmea conifera* weighed nearly 12 pounds and measured 18 inches in length, resembling a huge pine cone. This plant was reposing serenely and securely in the crotch of a limb over 80 feet from the ground. Secure it was until, with the assistance of three human "monkeys," we succeeded in loosening it from its aerial home and with ropes lowered it to earth. This epiphyte, including its several side shoots, weighed considerably over 125 pounds. From the ground this *Aechmea* did not greatly differ in appearance from *Aechmea depressa*, but the field glasses helped to convince me that it was another species. That meant another tough climb.

To climb these huge trees one must resort to monkey tactics and not try to tackle first the tree he wishes to conquer. A small tree possibly 50 feet away may be the first one to climb, for its upper branches will intermesh with those of the larger tree. And so with the assistance of ropes and vines the climber finally reaches the lower branches of the giant tree and then all he has to do is to finish the climb and get the plant, which may be accomplished in another hour or two.

But we forgot all about the difficulties of getting it when our thoughts turned to the perseverance and determination that a plant must have to be able to live perched at such a precarious height. With its huge reservoir to catch rain and vegetable matter it builds a body heavier than almost any of its terrestrial cousins, with the exception of some of the great Puyas of the high Andes. These great Aechmeas often hold from 1 to 3 gallons of water, which not only serves the plants themselves but also becomes a breeding place for animal life and even aquatic plants. Utricularias and aquatic mosses and algae are often found living in some species. In various specimens we found lizards, frogs, scorpions, small snakes, centi-

pedes, various insect larvae, roaches, ants, and bees, some preferring a particular type of bromeliad. The frogs that find a permanent residence in the deep, dark cylinders and cups of the bromeliads interested us most, and we made a small collection of them for Dr. Lutz. She has stated that "bromeliads make frogs independent of climate and environment, by creating a special environment."

In dry areas of Matto Grosso I found one of the biggest and most curious of the tree frogs, known as *Hyla venulosa* because of prominent veins in the eye. I had a hard time dislodging this one. It seemed to be stuck to the inside of the *Billbergia zebrina* where it was hibernating through a dry season. I shook and shook the plant but finally had to cut it open, and when I pulled the frog out of the little "canoe" of the bromeliad leaf, my fingers were all glued together. The frog had immediately thrown out his smoke screen, or rather, his rubber screen. When I touched him, a pure white latex oozed out of every pore of his body.

I am very sorry now that we did not bring back a good supply of these frogs. In the later rubber famine we might have helped solve a national problem!

The bromeliads apparently depend more on color to attract the fauna that act as an aid to pollinization than on perfume which in most flowers attracts the insects. Nectar gatherers that seem to have a special accord with bromeliads are the darting hummingbirds whose small, nimble bodies can get between the most complicated parts of a bromeliad flower and whose long, thin bills are especially adapted for efficient use in the tubular or deep-set flowers. Judging by the frequency of seeing hummingbirds at a brilliant bromeliad flower and also by the fact that hummingbirds would frequently hover around the red rain coat Mrs. Foster sometimes wore, I would say that they are attracted to the long tubes of bromeliad nectar more by color than by perfume. In Brazil they call these dainty little birds most appropriately "beija-flor," the flower kisser.

THE TERRESTRIAL RELATIVES

The most familiar bromeliad is the terrestrial pineapple. Because of its delicious fruit, much desired by mankind, it has become a great globetrotter and now seems even to be most at home in the Hawaiian Islands far from its birthplace in Central and South America. Since the form of the pineapple plant is typical of that of other terrestrial bromeliads, the Bromeliaceae have become known as the "pineapple family."

The pineapple type of foliage is common to many of the terrestrial genera. The more compact spiny types such as *Deuterocohnia*, *Dyckia*, and *Encholirium* resemble each other so much in foliage that unless

flowers are present it is almost impossible to identify them correctly. Being semisucculent and very efficient xerophytes, these plants withstand almost incredible conditions. In certain sections these formidable terrestrial bromeliads grow in such profusion that it is almost impossible to climb the rocky slopes, for the plants are as well armed with spines as any cactus I know—in fact, they are often mistakenly called cacti.

Many of these extreme drought-resisting species, like most of the cacti and other succulents, have endured adverse conditions for so many centuries that such conditions have become normal for them—adverse only from our point of view. They are conditions under which they thrive, and should the plant fall from a ledge or a tree to a moist, cool, shady spot, it would probably die. If it did not, its growth would be weak and abnormally fast. They have developed hardy qualities and are seldom found in the soft, shady places where the more tender ones such as Vriesias, Nidulariums, Neoregelias, or Billbergias seek cloister.

Dr. Smith believes that *Puya* is the most primitive bromeliad, and he is convincing in his argument against Mez's contention that the most primitive bromeliad is *Navia*. He suggests that probably Puyas came into being in the high Andes and that their offspring, meeting new situations, produced the various other genera. I, too, surmise that Puyas originated in the territory that is now the Andes, but I suggest that they came into being before the Andes rose to their present height, and that as the environment is presumably responsible for creating the various genera, they developed from ancestors that have since become extinct.

But what about the genera, morphologically very close to *Puya*, that are now on the eastern edge of South America, such as *Cottendorfia*, *Encholirium*, or *Prionophyllum* now isolated on the Atlantic coast of Brazil? Finding primitive types of bromeliads so far from their "parents," the Puyas, seems to indicate that in early ages many of these genera perhaps did not evolve from the Puyas but developed simultaneously as a result of their environment. *Encholirium*, *Lindmania*, *Deuterocohnia*, and *Cottendorfia* are similar in construction to *Puya*, but that does not necessarily mean that they descended from *Puya;* they could have evolved from other ancestors now extinct.

During the period of our two extensive trips into Brazil we collected in three extremes of country which produced the terrestrial species morphologically nearest to the primitive species of *Puya*. In the Matto Grosso on the Bolivian border we were as close to the "source" as our trip permitted.

Rising out of the vast marshes in southern Matto Grosso was the strange mountain Urucum, 2,000 feet high and 75 percent manganese ore. Dry areas were always presenting themselves in unexpected

places in Brazil, and this was one of them. Instead of the usual moist, humid forest on the mountainsides, we found a dry, dusty jungle of bamboos and dwarf trees through which for hours we hacked our way with sharp facão. It was here that we found *Deuterocohnia Meziana*, that unique bromeliad whose 5- to 7-foot flower stem continues to bloom for years from the same stalk. It grew as well on limestone rocks overhanging the Paraguay River as on the manganese rocks. Unlike most of the bromeliads, this plant is caulescent. I have seen overhanging the high rocky ledges specimens probably 50 years old, with large, ridged trunks that gave them the appearance of prostrate yuccas.

In evolutionary development *Deuterocohnia* is so close to *Puya* that it seems to be but an advanced form of that genus "distinguished by the advanced characters of appendaged petals and woody habit."[3]

In central Brazil, on the edge of the high plateau in the state of Minas Geraes, we found other terrestrials that were relatives of the pineapple and close to the primitive form of *Puya*. This is a section of mines—gold, iron, and diamond. In every direction we could see the effect of the vast deposits of ores in the soil, and at evening the purple haze, mingled with red and yellow glints from the sun, made a glowing spectacle radiating earth colors seldom seen outside of a mining district.

It was in this section that Glaziou, the French botanist who spent the latter part of his life in Brazil, did considerable collecting. He was a bromeliad enthusiast, and in his years of collecting he discovered some 65 new species in this family, a greater number than any other collector had ever found. It was interesting to find many of his species, and in a number of cases our specimens were the first found since the type was named. It was a keen satisfaction to be able to collect two new Dyckias and three new Vriesias in the rather arid rocky areas of Minas Geraes (with promise of still other undescribed species in the material obtained).

In most of these rocky areas one would expect to find cacti, as in Mexico, but in parts of Brazil most of the soil is acid, whereas the regions of Mexico in which cacti thrive are alkaline. So in Minas Geraes cacti were the exception rather than the rule. We seldom found bromeliads and cacti together.

In southern Brazil our collecting was confined to Paraná, where *Dyckia encholirioides* was typical of the primitive terrestrials near *Puya*. Unlike other Dyckias, it grew on bare granite rocks on the Atlantic coast at as low an altitude as 6 feet above sea level. Its species name indicates how close are the Dyckias and Encholiriums. *Dyckia encholirioides* is one of the few Dyckias that have developed

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[3] Smith, L. B., Geographical evidence on the lines of evolution in the Bromeliaceae. Sonderdr. Bot. Jahrb., Bd. 66, Heft 4, p. 460, 1934.

a trunk 7 or 8 feet long. Most of the Dyckias increase by stolons or side shoots and form bed masses of plants.

Clinging to the granite rocks in a similar position on the Atlantic coast, but much farther north in the state of Espirito Santo, we found a new *Encholirium*. This, too, had developed a prostrate trunk, and it might well have been named *Encholirium dyckioides*, but my description convinced Dr. Smith that the best name for the plant was *Encholirium horridum*, for my flesh was badly scratched and torn when I cut my way over a huge colony of these plants with their formidable, stiff masses of barbed leaves. This was the first species of *Encholirium* to show a branched inflorescence. It was the second new species in the genus for us, as we had discovered our first new one in Bahia and named it *Encholirium Hoehneanum* in honor of Dr. F. C. Hoehne of São Paulo.

One of our trips took us into both dry and humid territory in Bahia, northern Brazil. Here was a wide range of conditions, varying from the hot sands of the sea coast, where we found our new *Hohenbergia littoralis*, to the dry caatinga similar to the mesquite lands of Mexico. In this dry, shadowless desert covered with thorny, harsh vegetation punctuated with a few tall cacti we found the new *Cryptanthus bahianus*. During our month there we added nine new species to the total from that state, including *Cryptanthopsis navioides*. Of this latter genus only one species had ever been collected, and that by Ule some 30 years ago. This interesting whorl of delicately spined, stiff, grasslike leaves grew in a moist ravine in extremely dry country, a habitat similar to that preferred by most species of *Cryptanthus*.

Under the open, thorny vegetation we found another individualistic bromeliad, *Neoglaziovia variegata*. The dull, brown-green leaves of this plant with their vivid whitish bands look at first glance like snakes. In Brazil it is one of the most useful bromeliads, having been used by the Indians for centuries—and now on a commercial scale—as a source of excellent fiber which is stronger than sisal and makes a cloth that is softer than linen. The natives call the plant *caroa* or *caraguata*, names that are also used for several other kinds of terrestrial plants that yield fibers.

I am convinced that the type of country tends to produce the change in plants that creates varieties and species, and certainly it is the adaptability of the bromeliads that has made the family so prolific. Plants with this quality, like people, go places and do things and make the best of a situation even if they have to change their color, habits, food, or methods of travel. Every hundred feet of elevation, and sometimes even every mile from the sea, one sees a change in the bromeliads. When soil conditions, rocks, precipitation,

and air currents differ, the bromeliads which have adapted themselves to these changes will be different.

It was especially interesting to observe the continually changing parade of species during the ascent of Mount Itatiaya, which is nearly 10,000 feet high. At every rise of a few hundred feet, new bromeliads would appear, and then gradually disappear as we reached higher plant strata. And yet one *Vriesia* and one *Aechmea* started with us near the bottom and stayed with us until we had almost reached the top. But as we passed the tree line, they were left behind, although they attempted to stick it out on the sides of some of the large boulders. At the top, the exposure to wind and cold was too great for them, and they relinquished the territory to the *Fernseea itatiaiae*, the range of which is restricted to this mountain top. It is the sole member of its genus and seems completely satisfied with its isolation. It withstands frost, sun, wind, and drought and requires only the modicum of food that can be obtained from small crevices or cracks in the boulders.

Aechmea nudicaulis, on the other hand, has not been satisfied and has wandered all over the American Tropics. We found it in Mexico, Cuba, Trinidad, and Brazil; it is profuse in Central and South America. It lives in trees or on rocks in the coastal area and generally enjoys either sun or shade. With its range extending for thousands of miles, its plant form and its flower do not show as much variation as one would expect.

On the shadowless sand dunes of the Atlantic coast in the state of Espirito Santo we found another *Aechmea* as yet not definitely determined but undoubtedly close to *A. nudicaulis*. It is a stiff, gray-brown, tubular plant, almost metallic in texture. It grew right up to within a few yards of the sandy beach. Almost by its side we found a new *Portea* with short, stiff 18-inch leaves. This same *Portea* we found again growing on mangrove trees in a swamp, just a few feet above the water. There its leaves were narrow, limp, and 6 feet long. The stiff *Aechmea*, however, refuses to grow rapidly no matter where you place it, and while it does change to a more greenish cast in color in certain locations, its growth still remains slow, stiff, and rough.

An example of what happens to certain plants if the conditions are changed is found in *Billbergia Meyeri*, which I found in palm boots in harsh, dry country on the western border of São Paulo, where it was exposed to both extreme drought and torrential rains. We brought some of these plants back with us. Those that I kept in full light and gave no water retained their original shape; the plants kept in the shade made rapid growth and produced leaves three times their original length. When seeds of this species were planted,

they germinated in 2 days; at the end of 4 weeks they were 6 inches high and ready to be placed in pots. At 3 months of age they were glabrous, succulent, green as grass, and showed no trace of resemblance (as most bromeliads do even at an earlier age) to the parent plant, which is a gray-brown, blotched plant with a texture like emery paper.

Some of the species that have a wide range will vary so much in plant form, and at the same time have flowers so much alike, that they would exasperate almost any botanist. Again, there are many species, especially in the genus *Vriesia*, in which the plant forms appear to be almost identical, but which have entirely different flowers. I suspect that many botanists have passed by some of these more closely similar plants without realizing that there might be a new species among them.

I have had one advantage over the botanist who collects only blooming or fruiting material. I take the living specimens as well as the herbarium material, and the plants coming to bloom at a later date in my greenhouse have given me fresh material to be studied before the process of drying destroys certain characteristics. They have also given me flower material which I would otherwise not have procured unless I had made another trip in some other season.

From the hundreds of visitors who come to our Orchidario in Florida to see the plants we have gathered comes an almost universal exclamation: "It must be thrilling to go into the jungles and get all these wonderful plants!" They see the romance only; we, too, see that romance as we look at the interesting flowers and plants. But we recall also other things that intensify the memories of tropical exploration—the bites of mosquitoes, carapatos, bichous, and giant ants, the stings of huge swarms of bees and wasps, the penetrating of areas where malaria, yellow fever, or Chagas' disease is prevalent, the difficulties of transportation, food, water, and shelter. And invariably the most beautiful flower is safely perched just beyond the point that is possible to reach.

And not the least of these memories is the preparation of thousands of herbarium specimens. These specimens may have to be made from a 14-pound juicy flower head or from stiff, spiny leaves 9 feet long. They must be preserved regardless of the weather—in tropical rains and heat, or on cold, humid mountain tops. It is the surmounting of all these difficulties and conditions that produces the romance for our memory. But it is this part of the affair that would take most of the romance out of a jungle experience for many people, so they collect their jungle flowers from the florist.

1. TILLANDSIA RECURVATA.

A pineapple relative that thrives on telephone wire.

2. A PRESSING ENGAGEMENT.

Mrs. Foster prepares herbarium specimens from collected plants while breakfast cooks. The specially designed and well-equipped botanical truck of the state of São Paulo provided sleeping quarters as well as a complete stock of food, fuel, and necessary scientific apparatus so that long collecting trips could be made with great efficiency.

1. A CONTINUAL TOBOGGAN SLIDE.

Tillandsias rushing down the steep slopes of a mountain at the breakneck speed of half to three-quarters of an inch a year. *Tillandsia pulchella* var. [illegible].

2. TILLANDSIA DECOMPOSITA.

The epiphyte of Mato Grosso which in maturity dispenses with roots and allows its leaves to curl tenaciously around small twigs within its octopuslike grasp.

1. AGES OF WIND.

This is but a corner of Villa Velha where stand great sandstone monoliths, each one a lonely continent, shaped by the winds of countless centuries. As the earth tide ebbs, high and dry, these fantastic forms are left inhabited only by invincible plants, trees, and palms; and the last ones who win this race of time will finally die of starvation.

2. STREPTOCALYX FLORIBUNDA.

A giant epiphyte with leaves 9 feet long.

1. NIDULARIUM INNOCENTII VAR.
A striking bromeliad whose white flowers bloom in its water-filled leaf reservoirs.

2. THE DIOECIOUS CRYPTANTHUS.
This condition of separate sex flowers, unique in the Bromeliaceae, was observed in January 1942.

1. SEARCHING HIGH.

No tree was too high, no effort too great when visiting the occupants of lofty arboreal penthouses.

2. COLOSSUS.

Not a pine cone or a pineapple, but the flower head of a huge air plant that grew 110 feet up in a towering jungle monarch. It took three human monkeys over 2 hours to get it down; the one plant weighed over 100 pounds. It proved to be a new species and is called *Aechmea* [illegible].

1. EPIPHYTIC REFUGE.

Many bromeliads are a perfect retreat for fauna that like dark, moist places. One bromeliad when cut open revealed grubs, worms, and a large colony of ants.

2. AECHMEA MACROCHLAMYS.

A new epiphyte which was the winter home of four poisonous snakes.

1. HYLA VENULOSA.
From every pore there exuded latex, pure rubber.

2. ON MOUNT ITATIAYA.
Collecting the epiphytic relatives of the pineapple on Itatiaya, one of the high mountains of Brazil.

1. AN ARISTOCRATIC PINEAPPLE.
A feast for the eyes as well as the stomach.

2. DYCKIA ENCHOLIRIOIDES.
This is one of the few Dyckias which has developed a trunk 7 feet long. Found growing on granite rocks as low as 8 feet above the high-water line on the Atlantic Ocean.

1. DEUTEROCOHNIA MEZIANA.

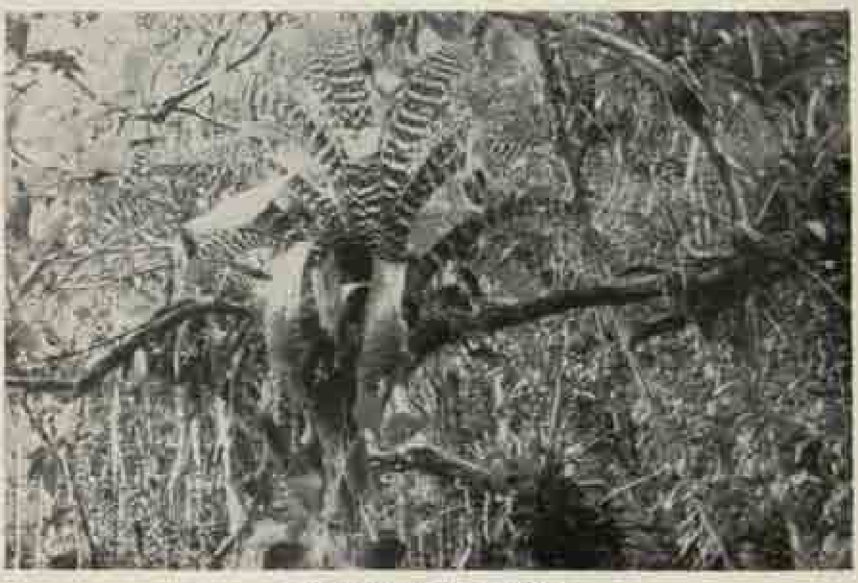
That uniquely individual bromeliad whose 5- to 7-foot flower stem continues to bloom for years from the same stalk. It is happy on calcareous as well as manganese rocks. The mountain Urucum is in the distance.

2. NEOGLAZIOVIA VARIEGATA.

A bromeliad source of excellent fiber, stronger than sisal and softer than linen.

1. VRIESIA ERYTHRODACTYLON.

This epiphyte blooms a transparent cock's-comblike flower head. It is singularly beautiful.



2. VRIESIA HIEROGLYPHICA.

One of the bizarre beauties of the coastal rain forests has decided protective coloration in its zigzag mottling.

CANADA'S INDIAN PROBLEMS [1]

By Diamond Jenness
Chief, Division of Anthropology, National Museum of Canada

[With 4 plates]

If you study a physiographic map of Canada, or, better still, if you travel over the Dominion in an airplane, you will find yourself irresistibly compelled to block off the country into four regions, viz, Canada east of the Great Lakes, the prairies, the Pacific slope, and the far north. Even then you will not be satisfied, but will begin to subdivide these four regions, to distinguish in eastern Canada, for example, between the fertile lowlands in southern Ontario along with the valley of the St. Lawrence, and the rocky uplands, splattered with innumerable lakes and rivers, that comprise the largest part of the two provinces, Quebec and Ontario. Each region, each subdivision of a region, differs from the rest in climate, in vegetation and in fauna; and since the less civilized man is, the more deeply he is influenced by his physical environment, so our Canadian Indians, when they first came into contact with Europeans, were likewise separable into a number of divisions—divisions that corresponded more or less with the geographical ones, but derived from differences in the mode of life, social organization and religious beliefs. It was due to these differences, in no small measure, that our Indians responded so variously to European contact, and that they vary so greatly today in their adaptation to European civilization.

Europeans first established a foothold in the eastern part of Canada, where they encountered two types of Indians, nonagricultural, migratory Algonkian tribes of the Maritime Provinces and of the upland areas of Quebec and Ontario, and corn-raising, semisedentary Iroquoian tribes of southern Ontario and along the banks of the St. Lawrence. These Iroquoians were themselves comparatively recent immigrants into Canada. A few centuries before they had lived to the south, either in Pennsylvania or within the basin of the Ohio River, where from neighbors still farther south they had learned to cultivate corn, beans, squash, and tobacco. But during the 300 or 400 years that had elapsed between their irruption into Ontario and Jacques

[1] Reprinted by permission from the America Indígena, vol. 2, No. 1, 1942.

Cartier's voyage up the St. Lawrence River in 1535, they had struck an adjustment, as it were, with the nonagricultural Algonkians who bordered them west, north, and east, an adjustment not unlike that between the nomadic desert dwellers of Arabia and the settled villagers on the fringe of the deserts. The Algonkians, that is to say, hunted and trapped along the lakes and rivers, transporting their birchbark wigwams on toboggans during the winter months and in birchbark canoes during the summer, roasting their meat and fish or cooking it in portable birchbark kettles, but, generally speaking, keeping to themselves and avoiding the Iroquoians of the lowlands, though they did occasionally exchange a few furs with them for such luxuries as tobacco and corn. The Iroquoians, for their part, peacefully cultivated the fields near their clusters of shedlike huts, and their men hunted and fished in the vicinity while the women harvested the crops, manufactured clay cooking vessels, and performed numerous other tasks incidental to a settled village life.

Even in the sixteenth century, long before any European had penetrated inland as far as Ontario, Breton, Basque, and Portuguese fishermen and fur traders had disturbed this adjustment. They had upset the native economy by introducing iron tools and weapons, and by creating an unlimited market for furs, particularly for beaver, which led to the denudation of the game in certain districts and to widespread movements of the native population for trade and hunting. Trade rivalries and encroachments on the hunting grounds of others then engendered intertribal warfare that was aggravated by the introduction of firearms; and the Iroquoians of the St. Lawrence Valley and southward became bitter foes of the Algonkians who surrounded them on three sides, and of their own brethren in Ontario. Differences in the social and political organization immediately asserted their influence. The well-integrated Iroquois tribes federated for mutual protection (creating the well-known Five, later Six, Nations), submitted to the rule of an elected council and to the discipline of military chiefs, and through their military valor and skillful diplomacy during the colonial wars won for themselves ample farming lands and a semiautonomous status when those wars ended. On the other hand, the nomadic Algonkians, who lacked any close tribal organization but wandered from one hunting and trapping ground to another in small, semileaderless bands, proved incapable of uniting or of exercising great influence in the conflict between the French and English for supremacy on this continent; and, being a negligible factor, they were pushed more and more to one side by the ever-increasing flood of whites.

Nevertheless, even these Algonkians encountered alleviating conditions such as were lacking to the Indians over the greater part of western Canada, who did not come into close contact with Europeans

until two centuries later. The earliest French settlers in eastern Canada were few in numbers, primitive in their manner of life, and cut off entirely from the Old World except for the visits of one or two ships each summer. Furthermore, the vast majority were men who combined their simple farming with fishing and hunting, or neglected farming altogether for a life in the woods similar to that of the Indians. Yet Canada was their permanent home, not merely a place of work and residence for a few years, after which they would return to Europe, as did so many employees of the great fur-trading companies who operated in the west and northwest a century or so later. Nothing was more natural, therefore, than that many of these early French settlers should marry Indian girls, especially girls who had been educated in the mission schools; and that the free traders who roamed the woods should take wives from the Indians who supplied them with furs. We must remember that in the seventeenth century, the period that witnessed the laying of the foundations of New France, Indians and whites were on a more nearly equal footing economically than they were a century later, when numerous industries such as milling, weaving, and iron-working established themselves in the Maritime Provinces and along the banks of the St. Lawrence. Hence intermarriage occurred quite freely, half-breeds experienced no disabilities of any kind, and both half-breeds and Indians received every encouragement to participate with the white settlers in building up a prosperous colony. How many actually merged with the whites we shall never know, but the proportion was not inconsiderable. Many, of course, found the drudgery of farm life too difficult and preferred to maintain their old hunting and trapping existence, which was indeed the only existence possible north of the St. Lawrence watershed; and it is they, or rather their descendants, who occupy most of the present-day Indian reserves in eastern Canada or roam over northern Ontario and northern Quebec. Yet even they were witnesses, and to a limited degree, participants in the slow rise of eastern Canada from a few settlements of primitive colonists to a great agricultural, industrial, and commercial area, and they were given ample time to adjust themselves to the changing conditions that unfolded themselves century after century.

It was otherwise on the great plains, whose inhabitants had to withstand the shock of two sudden revolutions, both brought about by whites directly or indirectly. We actually know very little about the life of these Indians prior to the first revolution, because the only explorer who visited them before that time was the youth Kelsey, and his account of his journey is extremely meager. In his day (1690), apparently the only true plains' dwellers were the Blackfoot and the Gros Ventres; for the other tribes that later disputed the area with them, the Sarcee, Assiniboine, Cree, and certain bands of Ojibwa,

clung to the forests at this time and made only brief incursions onto the treeless prairies. Kelsey found the Blackfoot wandering on foot in small bands that ceaselessly pursued the numberless herds of buffalo. He met them, however, in summer only, and whether or not they too retreated to the edge of the forests at the onset of winter is uncertain. Less than 50 years later they had obtained horses from a United States tribe to the southwest and a few guns from Hudson Bay. At the same time the neighboring Sarcee, Cree, and Assiniboine Indians had begun to press into their territory, and to demand a greater share of the buffalo hunting now that the mobility given by the horse and the effectiveness of the firearms had made hunting easier and more profitable. Rivalry in war and the chase then brought about internal reorganizations in all the tribes. Some of them graded their young men into semimilitary societies and adopted a circular form of encampment with the tent of the highest chief in the center. All alike elevated warfare to the level of a national sport, and instituted a regular system of rewards for the taking of scalps and the capture of guns or horses.

So it came about that the plains became one vast guerrilla zone in which men hunted and were hunted without cease. The dress, the customs, even the religion of the Indians reflected the change that had taken place, and under uniform geographic and economic conditions tended to become uniform also. Every tribe, for example, adopted the institution of the sun dance, and possessed its quota of precious medicine bundles, each with its individual ritual.

All this time, however, Europeans were slowly filtering into the prairies from the north, south, and east, and the indiscriminate massacre of the buffalo herds by both races was rapidly destroying the foundation of the Indians' economic life. By 1879 the great herds had ceased to exist and the old free hunting life suddenly collapsed. With almost no warning the starving Indians were confronted with their second revolution. Henceforth they had to confine their movements within narrow tracts of land set apart for them by disdainful white overlords, and to divert their energies from the exciting buffalo hunt, with its intervals of pleasant idleness, to the monotonous drudgery of farming and ranching, tasks which their forefathers would have regarded with contempt. We cannot wonder that most of the ex-warriors of the first generation lost heart at the abrupt transformation, and that for a period the population of the plains' Indians registered a decline.

Similar declines of population are not rare. On the contrary they have occurred in British Columbia, in parts of Africa, and throughout almost the whole of the South Seas; so commonly, in fact, during the last 200 years as to be almost the rule wherever uncivilized peoples have been suddenly confronted with European civilization. Not one

cause only is responsible for it, but a number of related causes. Changes in the economic activities and in diet have played their part; for example, our Mackenzie River Indians are now more or less permanently undernourished, as are many natives in other parts of the British Empire. Then, again, epidemics of previously unknown diseases have ravaged the native population in all parts of the world (measles, for instance, wiped out 40,000 Fijians in one year). Perhaps the most important factor, however, has been the failure of the natives to reorient their lives under European hegemony and to establish themselves on a secure economic basis that preserved both their dignity and their feeling of independence. The loss of their economic security and the degradation of their social status has destroyed their self-respect, robbed them of all aim and ambition in life, and lowered their morale to such an extent that they consent more or less consciously to the signing of their own death warrants. Very often the fault has lain not with the natives themselves, but with their European overlords; for only too commonly white governments have failed to realize their responsibilities toward their native subjects, and have allowed individual whites either to exploit them, as they exploited the Kanakas on the Queensland plantations, or to push them to one side as encumbrances, as happened to the Australian blacks.

One prairie tribe, the Blackfoot, suffered less from the economic shock and the ravages of diseases than the rest, for a reason we shall see presently; and, within the last 20 years, all the plains' peoples have shown signs of recovery and of a slow increase in population, even though the economic conditions on some reserves are still far from satisfactory. A recovery of this kind is not uncommon either; it is occurring today, for example, among the Eskimo, and among the Maoris of New Zealand. And just as many causes operated, often in conjunction, to produce the previous decline, so there seem to be many causes for the recovery. In the Tropics, climate undoubtedly exerts an important influence, because Europeans cannot develop the Tropics without native labor, and a growing realization of their indispensability increases the natives' economic security and social independence. Both within and without the Tropics, again, natives whose economy was already based on agriculture have generally fared better than those who, like the Australian blacks and most of our Canadian Indians, supported themselves entirely by hunting and fishing; for the new regime, while greatly modifying their daily life, has not demanded a complete transformation. It is partly for this reason that in eastern Canada our agricultural Iroquoian tribes have prospered more than the previously nonagricultural Algonkian, even where the latter have been placed on reserves with equally fertile soil.

We can discern still another reason, however, for the greater pros-

perity of the Iroquoians, and particularly of the Five Nations. At the time of their greatest crisis, i. e., at the close of the colonial wars, they were organized into a more compact unit than the Algonkians, and they were led by men of courage and vision like Joseph Brant. The same factors account for the resilience of the Blackfoot. It was the able leadership and far-seeing wisdom of their chiefs, especially of Crowfoot, that braced them against the shock of confinement, encouraged them to direct their energies to the growing of wheat and the raising of cattle and horses, and maintained their morale at a high level while that of the other plains' tribes languished. These two examples from our Canadian Indians—examples that could be multiplied the world over, among civilized and uncivilized peoples alike—illustrate a truth that we often overlook, viz, that the strongest forces for the regeneration or upbuilding of peoples come from within their own ranks, not from without. Always the driving force is some seemingly high and noble ideal, but this ideal may lie dormant for years and even centuries (as did the longing for liberty in Finland and Poland) unless some great leader arises to give it voice and to carry the people with him. Every administration that deals with a native race, therefore, should aim, first of all, to inspire or foster in that race some desirable goal, and then to promote the evolution of native leaders who will command the confidence of their people and guide them toward that goal.

The steadfastness of the Blackfoot when they were first confined to reserves, and the progress they have made since in readjusting their lives, scarcely affected the other plains tribes, whose partial recovery in recent years must be attributed to their own vitality. As the older generation passes away and the traditions of war and buffalo hunting fade more and more from memory, the younger Indians in these tribes are gazing out on a new world. Occasional travel by rail, but especially by automobile, is helping to enlarge their outlook, and the hopelessness that gripped them when they were first banded on reserves is slowly passing away. They have noticed the economic distress of the white farmers on the prairies during the last decade, and they are realizing more and more each year that, however benevolent the government may be, however it may protect and safeguard them, in the last analysis their future and that of their children depends principally on their own personal efforts.

Our picture changes completely when we pass to the Pacific coast. There the climate is milder, the vegetation and fauna very different from those in other parts of Canada. Any inland tribes that pushed their way thither through the barrier of the Rocky Mountains found conditions so favorable that they never returned. Actually the main population drifts seem to have been from Alaska southward down the interior plateau or along the coast. The region was largely a cul-de-

sac whose inhabitants, though ignorant of agriculture, evolved an amazingly rich culture on the foundation of their local resources. These resources were themselves unusually rich. The sea and rivers yielded fish in astonishing abundance, wild fruits were plentiful, and the forests supplied magnificent timber that was easily worked with stone or bone tools.

At numerous places along the coast line, then, there stood in pre-European days villages of plank houses such as existed nowhere else in America. Some of these houses were of extraordinary size, and adorned with those enormous carved pillars that we now commonly call totem poles. The villagers themselves roughly separated into three grades, nobles, common people, and slaves, the latter either prisoners taken in raids on neighboring communities or the descendants of such prisoners. With abundance of food, particularly of salmon, life was rather easy, and the months of autumn and winter were devoted largely to entertainments, both secular and religious. The nobles, who acquired their status by inheritance, vied with each other in giving elaborate feasts or potlatches, and the ceremonies and rituals that accompanied these feasts stimulated the arts of weaving, painting, and wood carving, as well as music and the drama. In art and drama, indeed, the Pacific coast natives far surpassed all others in Canada; their unique wood carvings have attained a world-wide reputation.

A number of European vessels visited this British Columbia coast in the closing years of the eighteenth century, but colonization began only in the first quarter of the nineteenth, and then it was confined to a small district around Victoria. By the middle of the century, however, the tide of immigration was flowing in great strength, and already disrupting the economic and social life of the natives throughout the entire province. European disregard of all distinctions of rank, the abolition of slavery, and the introduction of new standards of wealth which the ex-slave could acquire more easily perhaps than his ex-master, destroyed every vestige of local authority in the villages, while at the same time the establishment of fishing canneries seriously interfered with their principal food supply. The mechanical age had just opened. Steamers were plying up and down the coast; lumber companies with snorting donkey engines and high-rigging tackle were invading the forests. With almost no preparation or warning Indians who had not yet fully emerged from the stone age found themselves caught in the maelstrom of modern industry and commerce.

The first result was a frenzied acceleration of native life. By hiring out their labor to Europeans, Indians who could never have hoped for social advancement in their communities were able to amass enough food, blankets, and other goods to hold great feasts or potlatches, to assume the rank and titles of nobility, and to extend their fame among all the neighboring villages. At the same time the introduction of

metal tools facilitated woodworking, and not only chiefs, but ex-commoners and even ex-slaves began to build enormous houses, to set up lofty totem poles, and to wear at ceremonies elaborately carved wooden masks. Rivalry among the more prosperous Indians increased the frequency and magnificence of the potlatches; men toiled and saved for years merely for the glory of entertaining 3,000 or 4,000 guests for 7 or 8 days. Finally, in some districts, the old custom of giving away presents at these potlatches—which was really a primitive banking system, since the presents were redeemable—degenerated into reckless squandering and even the wanton destruction of property. Naturally, this only increased still further the jealousy and strife, besides threatening widespread destitution. Accordingly, the government intervened and strictly prohibited all potlatches, including under that term every ceremony, religious or secular, at which the giving of presents had been customary. The turmoil in the villages then died down; but the measure was purely negative and had an unfortunate psychological effect. It destroyed the ambition of the natives by depriving them of their traditional means of social advancement without helping them to improve their economic and social position vis-à-vis the white population. Very few of them had successfully taken up farming. The majority worked for the fishing canneries, where the men had now to compete with well-organized Japanese fishermen; or they gathered fruit and hops, worked as dock hands in places like Vancouver, Victoria, and Nanaimo, or found employment in lumbering and similar occupations, for the most part seasonal, that provided only the barest subsistence. Civilization had burst upon them so suddenly that they were bewildered and unable either to avoid its evils or to see and grasp its opportunities. European diseases decimated their ranks and the population dropped at an appalling rate. Some of the girls married white men, or, in rare cases, Chinese; here and there a man broke away from his fellows and merged with the whites; but the greater number clung to their old settlements (which the government finally converted into reserves), and watched with hopeless, uncomprehending eyes the growth of industry and commerce around them. Scattered in tiny communities without any semblance of union, they could develop no leaders to guide them out of the morass. Their regeneration seems possible only from outside stimulus and leadership, such as is now meeting with success in Bella Bella and a few other villages.

It is interesting to notice that Japan, on the opposite side of the Pacific, was caught in the same maelstrom as our Pacific coast Indians, and at precisely the same time. Japan, however, was a densely populated nation with an ancient civilization grounded on the intensive cultivation of the soil. She possessed the tradition at least of unity, her political freedom was unimpaired, and her ruling nobles were able to pool their efforts and work out their country's salvation on a definite

plan. Our Indians, on the contrary, numbered only two or three score thousand individuals scattered through dozens of politically independent hamlets, and speaking half a dozen mutually unintelligible languages. Politically, they were incapable of uniting and presenting a common front, even if they could have found a leader. Moreover, they were fishermen and hunters who had never tilled the soil until the early Europeans taught them to grow a few potatoes. Hence when the fishing companies monopolized the runs of salmon, which had been their staff of life, each little community had to make its own adjustment and either change its mode of existence entirely or disappear.

If the Pacific coast with its abundance of fish was an extremely favorable area for human habitation, and indeed, before the coming of Europeans, the most populous region in Canada outside of southern Ontario, where the cultivation of corn permitted a greater concentration of population, the basins of the Mackenzie and Yukon Rivers, like northern Ontario and northern Quebec, were very unfavorable. The rigorous climate prohibited agriculture, even had it been known. Fish, while comparatively plentiful in the lakes and rivers, did not run in large shoals, like the salmon of the Pacific coast, and their capture involved extreme hardship during 6 months of the year. The real mainstay of the Indians was the caribou, which supplied not only food, but clothing and coverings for the tent; but in the forested areas the caribou roamed singly, not in great herds like the species on the barren lands, so that the Indians had to wander about in groups of two or three families, that feasted when the chase and fishing were successful and starved when they failed. Life thus alternated between plenty and starvation. The weaklings perished on the trail, since there was no fixed home where they could find shelter, or stable food supply that could tide them over a critical period. Few social amenities lightened the unending drudgery and hardships. It was a region of poverty, material and spiritual. Nevertheless, it enjoyed one blessing. It was a fairly peaceful region, because one area was scarcely preferable to another and the tribes had no inducement to encroach on each other's territories.

The advent of the fur traders in the seventeenth and eighteenth centuries destroyed this peace without relieving the prevailing poverty. The two tribes that bordered the fur posts on Hudson Bay, the Cree and the Chipewyan, tried to monopolize for themselves all the benefits of this trade. Equipped with guns, the Chipewyan reduced their neighbors, the Yellowknives and the Dogribs, to a state of serfdom, while the Cree pushed westward, drove out the Indians who inhabited the upper waters of the Mackenzie River and took over the territory for themselves. Turmoil and strife prevailed through the entire region until a terrible epidemic of smallpox toward the end of the eighteenth century carried off nearly half its inhabitants. Even then the tribal

enmities that had been engendered persisted, and occasioned more than one massacre in the first half of the nineteenth century. Peace has now prevailed for 100 years, missionary and tradings posts are scattered over the whole area, water and air transport are opening it up as a tourist playground, and the mineral wealth in its rocks is being exploited more and more with each passing year. Yet the Indians have failed to make any appreciable progress. Hunting (including trapping) and fishing still remain almost their sole means of subsistence, and the returns from these occupations are decreasing rather than increasing. It is true that the murderous blood feud has long been suppressed, that infanticide and the abandonment of the aged and infirm have ceased, and that there are now very few deaths from outright starvation. Nevertheless their standard of living is so low that the majority are permanently undernourished. This makes them ready victims of every sickness, particularly of tuberculosis, and, combined with the hardships of a hunting life, produces a very high mortality.

Now it is quite probable that these northern Indians have always been undernourished to some extent, and that it was partly undernourishment that made them less virile than other Indians, as their early history seems to indicate. It would explain also why, generally speaking, they have shown no resourcefulness in meeting the changed economic conditions of the last 100 years, or any desire to adapt themselves to their new environment. They are good canoemen and packers, tasks that they have performed for centuries; but in all occupations connected with industry and commerce they have shown themselves hitherto inefficient and unreliable. Their numbers are declining; both their economic condition and their morale are at a low ebb. Their regeneration is an exceedingly difficult task, hinging very largely on the economic resources of the territory (which are still imperfectly known), and on the development of these resources by the white man. The Indians are themselves one of the resources, for they are a fixture in the territory; they cannot, like white men who enter it, pull up their stakes and return south if the living becomes unprofitable. The chief problem therefore is to restore their morale, and to raise their standard of living by providing remunerative employment for which they will show some aptitude. And this will tax the wisdom of the most far-sighted government.

The Arctic coast of Canada was a realm of its own, and its inhabitants, the Eskimo, differed from all the other aborigines of America in language, appearance, mode of life, and—what is less often stressed, though it has tremendous influence on a people's survival—in temperament.

There is no need to describe Eskimo life—how it rested solely on fishing and hunting, particularly the hunting of sea mammals, and

how it varied in different parts of the Arctic, and at different seasons of the year. Inevitably it involved great hardships, and the mortality everywhere was very high. In the Canadian Arctic especially the population density was extremely low owing to the comparative scarcity of sea mammals; long stretches of coast line carried no inhabitants at all. The total number of Eskimo-speaking people today, from the shores of eastern Siberia to Greenland, is only about 38,000; and there is no evidence that it ever exceeded that figure.

It was in Greenland that Europeans first discovered the Eskimo, at the end of the sixteenth century, if we leave out of account the early Norsemen, whose colonies were *spurlos versenkt.* During the next few decades these Greenland Eskimo, like those of Canada and Alaska later, were demoralized by the crews of whaling ships and decimated by European-brought diseases. In the eighteenth century, however, Denmark insulated the country by making all trade a government monopoly and began to administer it on the principle of "Greenland for the Greenlanders." Eskimo became the official language throughout the island, and its inhabitants were granted in time a considerable measure of self-government. During the last hundred years the population has steadily increased until now it exceeds 17,000. Intermarriage with whites takes place quite freely, and most of the present-day Greenlanders carry in their veins a greater or less percentage of Danish blood.

Whaling ships did not frequent Hudson Bay and North Alaska in any numbers until the second half of the nineteenth century. There too they left a diminished population, one that had become equipped with rifles and metal tools. Nevertheless, they did not greatly disturb the daily routine of Eskimo life as it had existed for centuries. The fur traders who succeeded them, however, exerted a more permanent influence. Instead of hunting seals on the ice close to shore during the months of winter the Eskimo now trap foxes, and their diet at that season has changed in some regions from 100 percent meat and meat broth to 60 percent and even 70 percent flour and tea. Their clothing, too, has altered. Originally made entirely from caribou fur except the outer footgear, which was of sealskin, it now consists partly of woolen and cotton garments; and under the conditions that prevail in the Arctic these garments are seldom washed, and sometimes not even removed until they rot. Inadequate diet and unhygienic clothing are thus impairing the physique of the Eskimo in many places, even though there are fewer deaths from outright famine. Whether their numbers are still declining along the more northern coasts is unknown, since there has never been even an approximately accurate census until the last 10 years.

In Canada, as in Alaska, the authorities have made no attempt to isolate the Eskimo. Subject to certain regulations, Arctic Canada is

open to all and trade is free, though the Hudson's Bay Company enjoys a virtual monopoly over a large area. No educational facilities exist apart from the rudimentary teaching of English in a few missions. In Alaska there are regular day schools in all the larger Eskimo centers; they too employ English as the medium of instruction. In the Greenland educational system both day and high schools employ the Eskimo language, though the teaching of Danish is now compulsory.

In dealing with her Eskimo population, therefore, Canada, like the United States, has followed an open-door policy that implicitly aims at rapid assimilation, whereas Denmark has adopted a policy of segregation and tutelage similar in many respects to Canada's policy with her Indians. The merits of the two systems have been widely disputed, not in reference to the Eskimo only, but in reference to many native populations the world over, even the colored population of the United States. In the South Seas, where Europeans have definitely rejected segregation, the Maoris are increasing in numbers and merging tranquilly with the whites, whereas in Tahiti and other islands their Polynesian brethren are rapidly declining. The Japanese have segregated the Ainu, Britain has insulated the Nagas of Assam, Belgium its pygmies in the Congo, South Africa its Bushmen and some of its Bantus; and Australia is considering the segregation of its blacks.

Now it is clear that segregation does not in all cases carry the same aim. No one expects, under the tutelage which segregation permits, that the pygmies of Central Africa, the Bushmen of South Africa, or the Australian blacks, will advance to such an extent that they can some day stand on their own feet in competition with other peoples. Segregation in their cases is dictated by considerations of humanity only, the same considerations that lead us to build old men's homes for the indigent poor. These natives are comparatively few in numbers, they are incapable, we believe, of making any important contribution to the progress of man upon this earth, and if they should become extinct within a few generations or centuries the world will presumably be none the poorer. Whether they are doomed to disappear quickly or to remain in tutelage for as long as we can foresee, our moral sense compels us to make their lives no less comfortable and happy than our own.

Not humane considerations only, but economic ones also inspire the segregation of certain Bantu tribes and of the Nagas of Assam. The numbers of these peoples run into millions, and they inhabit large areas of fertile tropical land that the white man, even if he tries to colonize, cannot develop without native labor. Hence he must either protect the local inhabitants and train them to develop their territories themselves (in the beginning, at least, under his hegemony), or he must permit their dispossession by Hindu, Chinese, and other peoples who are also adapted physiologically for a tropical life.

In the cases of segregation just noted there is no intention, explicit or implicit, to encourage any merging of the protected races with their protectors, because white people, particularly those of Anglo-Saxon and Teutonic stocks, have strong prejudices against intermarriage with colored peoples. (Japan, we may notice in passing, likewise discourages the intermarriage of her nationals with the Ainu). But when Denmark insulated the Eskimo of Greenland, and the United States and Canada placed their Indians on reserves, not only did they aim to raise the Greenlanders and the Indians up to the white man's cultural level, but they looked forward quite frankly to ultimate amalgamation. There was no color bar to prevent this amalgamation, no prejudices other than the economic and cultural. The natives were expected to mingle with the whites on equal terms as soon as they reached maturity and gradually to merge their blood. Hence the insulation or segregation of these peoples is merely a temporary expedient equivalent to the placing of orphan children in training institutions; it is a very different measure from the segregation of the Bantu and Bushmen tribes in Africa, or of the blacks in Australia.

It would be wrong to suppose that this segregation or insulation of the Indians and Eskimo aimed at eliminating every trace of their old cultures and blotting out their languages. Both peoples have already enriched our civilization in many ways, and may conceivably enrich it still further. In educating them to play a part in the economic and cultural activities of the modern world we desire to eliminate only such features of their former life as definitely hinder their progress and render them less adaptable. Accordingly, in Greenland, Denmark has promoted the use of the Eskimo language and the hunting of seals in kayaks; but she has also enforced the study of the Danish language and culture, has developed fishing into a large-scale industry, and, wherever possible, fostered new activities such as the breeding of sheep and goats to raise the economic level.

Canada's administration of her Eskimo has the same ultimate aim as the Danish, even though from geographical reasons it necessarily follows a different course. Greenland is an island that until recently was accessible only by sea during a few months of the year, and it lacks any large deposits of minerals except some relatively unimportant cryolite beds. Only its sealing had any attraction for foreigners, and that was located largely off the uninhabited northeast coast. In closing the country to foreign traffic, therefore, Denmark ran no risk of international complications, and in closing it to her own people she aroused no internal dissension, because it was not a field for colonization or for any enterprise that looked for profits. Whether it has been closed long enough, and whether the Greenlanders, now admittedly more European than Eskimo, can successfully administer their own affairs, is a

question that is being keenly disputed in Denmark. We may leave it to that country's decision and contrast the Canadian Arctic.

The Eskimo population of Canada has always been much smaller than that of Greenland (it numbers today, including Labrador, only about 6,500); and it is distributed over many times the length of coast line, so that the settlements are farther apart and more isolated. Moreover this coast line (even Baffin Island) is an integral part of the mainland of America, accessible both by land and by sea. The highly mineralized pre-Cambrian zone touches it in several places, and each year air transport brings the most remote areas into closer touch with the centers of civilization farther south. Today the region between Great Slave and Great Bear Lakes is experiencing a mining boom; next year it may be the hunting grounds of the Eskimo between Great Bear Lake and the Arctic Ocean. No administration, therefore, could possibly insulate the Canadian Eskimo from the outside world unless it concentrated them into one area, e.g., the northern archipelago or the region round the Magnetic Pole; and in that narrow space most of them would perish from starvation, so limited are the food resources. Moreover, no one can foresee the future of aviation. It is quite possible that within the next 20 years airplanes will be flying on regular schedules between Europe and America over the Canadian Arctic, and that the region will be dotted with emergency landing stations.

Insulation or segregation of the Canadian Eskimo is therefore impossible. They must sink or swim in civilization's tide, with no period of tutelage to equip them for the struggle, and with only such protection as an open-door policy will permit. Even their language will disappear before many generations, because their settlements have little or no contact with one another, but trade almost exclusively with white men who only rarely understand their tongue. To preserve its identity and its language in the face of outside pressure a people requires the cohesion given by population mass, and this the Canadian Eskimo definitely lack.

Nevertheless, the temperament of the Eskimo is the strongest guarantee of their survival, though not as a separate people. Whether because or in spite of their difficult environment, they have developed through the ages a most unusual cheerfulness and resourcefulness that have already withstood the shock of European impact and will carry them through the adjustment period. Their temperament will facilitate their intermarriage with Europeans and leave its mark on their descendants, so that in years to come the American Arctic, no less than Greenland, will be inhabited by hardy frontiersmen carrying in their veins a strain of Eskimo blood, but speaking a European language.

THE INDIAN VILLAGE OF LORETTE NEAR QUEBEC CITY
Photograph by C. M. Barbeau.

1. AN INDIAN WOMAN SHELLING CORN.

2. INDIAN COWBOY IN THE CHILCOTIN DISTRICT OF BRITISH COLUMBIA.

Photograph by Harlan I. Smith.

1. VILLAGE OF MASSETT, QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA, IN 1879.
Photograph by G. M. Dawson.

2. VILLAGE OF MASSETT, QUEEN CHARLOTTE ISLANDS, BRITISH COLUMBIA, IN 1919.
Photograph by Harlan I. Smith.

1. A Danish Trapper with his Eskimo Wife and Family.

2. Crowfoot, Chief of the Blackfoot Indians When They Were Confined to Reserves, and His Family.

DAKAR AND THE OTHER CAPE VERDE SETTLEMENTS[1]

By Derwent Whittlesey
Harvard University

[With 4 plates]

Dakar is the only city, in the European (or Occidental) sense, in the whole of West Africa. No other center shows the clear-cut areal differentiation of functions that characterizes the *urbs occidentalis*. Its urban—in a small way even metropolitan—character cannot be attributed to its creation by Europeans less than a century ago, because this differentiation of functions has evolved only during the past three decades. The absence of any significant settlement on or near its site until the late nineteenth century heightens the paradox of its present ranking position among rivals, whether newly founded or centuries old.

The enigma of Dakar promises solution if the city is considered in association with its intimate neighbors. Together they form a design in historical geography close to the typical for tropical Africa. Europeans, upon their advent in the period of the discoveries, traded intermittently with indigenous farming and fishing villages of the Cape Verde Peninsula. Subsequently they established a stronghold on an island close to shore as headquarters for trade and administration of affairs. In time a lighterage landing place on the continent absorbed the commerce, leaving to the island its political functions. Finally, an artificial harbor on the continent proved sovereign over both its predecessors and drew to itself all the functions both had exercised, adding to them new functions of its own.

In this course there is nothing to set Dakar apart from several other places along the coast. Its preeminence appears natural, however, in the light of the shifts in items, values, and routes of African trade during five centuries, the quality of the unique location amid revolutionary changes in the political and technological structure of the world, and the variety of the associated sites, which permitted flexible utilization to suit advancing needs.

[1] Reprinted by permission from the Geographical Review, vol. 31, No. 4, October 1941, published by the American Geographical Society of New York.

THE INDIGENOUS AFRICAN SCENE

THE PHYSICAL SETTING

Seen from an approaching ship the westernmost land of Africa emerges above the horizon as a group of cliffed islands, flat or gently rounded. A nearer view discloses that the highest of these eminences are linked by a somewhat lower platform, behind which low ground extends northward and eastward. A map (fig. 1) shows this low ground to curve on each side in a wide concave arc to the mainland of the continent, 40 kilometers away.

This peninsula is the Cape Verde tombolo, product of emergence combined with deposition by waves and currents. The promontory called Cape Verde faces west, and behind it rise the rounded Mamelles, the western and higher one to 103 meters. Some 10 kilometers to the southeast is Cape Manuel, a cliff of columnar basalt rising 40 meters out of the sea. Between these heights somewhat lower ground is capped by altered limestone, which juts out in promontories to make a festoon of coves all around the headland.

The higher cliffs are skirted by talus, and at their base the waves break on beaches of large black boulders. Sand, worn from the limestone or brought from the Sahara by marine currents, has softened the physiognomy of the coves on the seaward faces of the peninsula. On the north, strong surf and north winds have heaped beach and dune the length of the shore line. On the inner face, the long, sandy curve of beach that forms the south shore of the tie to the mainland gives way to the headlands of the south-trending coast. The coves between these heads are progressively less sandy, the southernmost having a stony beach. Unlike the coves on the Atlantic side, they are not silted by the predominant northerly winds and receive increments of sand only from the beach to leeward. The tombolo bar is 4.4 kilometers wide at the narrowest point and 40 at the base.

Two basalt islands not yet tied to the mainland flank Cape Manuel. They are only slightly lower, and they duplicate in miniature the physical character of the peninsula. A few low islets sprinkled off Cape Verde are a menace to navigators but are otherwise negligible.

The basalt islands and Cape Manuel are waterless and barren. In the rainy season the limestone plateau is moistened by seepage from dunes standing upon it. On the calcareous sands of the tombolo bar the uninterrupted beaches convert streamlets into backwaters and marshes, and the lines of fixed dunes act as reservoirs feeding water into the depressions throughout the year.

A few palms fringe the marshes, but elsewhere the native trees are baobabs, which dot the peninsula and give it its often-described

FIGURE 1.—The Cape Verde Peninsula. Scale approximately 1 : 300,000. Based on the 1 : 100,000 map of the Service Géographique de l'Afrique Occidentale Française à Dakar, 1928.

distinctive appearance.[2] Whether or not the landscape appears green enough to justify the name "Cape Verde" depends on the time of year. Throughout the long dry season, lasting from October until June, the gray, silo-shaped trunks of the leafless baobabs, the dusty, parched grasses, and the stubble of millet make a drab scene. Doubtless even this, however, would look refreshing to sailors from Europe, dazzled by the hundreds of miles of sand-dune coast that borders the Sahara. When the rains come, the Cape does turn incontestably verdant. The baobabs leaf out, the marshes fill and put forth new growth, and the plains push up a stand of millet that grows 6 feet tall in its brief life.

All this verdure is the product of downpours between mid-June and late October (table 1). The peninsula lies in the belt of semiarid

[2] Claude Faure, Histoire de la Presqu'île du Cap Vert et des origines de Dakar, p. 17, Paris, 1914, quotes some of the descriptions.

climate between the arid Sahara and the Sudan, where rainy and dry seasons are of about equal length. As in all other semiarid regions, its rainfall is unreliable. The heaviest cloudbursts are brought by the rather infrequent "tornadoes." These may occur at any time during the rainy season but are likeliest at the beginning. Dense clouds pile up swiftly from the east, sky and sea turn black, and a violent thundersquall ensues. Within half an hour the wind turns west and the storm is over, but rarely without damage to trees and habitations.[3]

TABLE I.—*Rainfall in Dakar, average for 1903–1933*[3]

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Rainfall (mm.)	1	1	0	0	0	17	74	202	137	41	2	5	540
Rainy days	1	0	0	0	0	3	7	14	11	3	1	1	41

Maximum annual rainfall (1906), 947 mm.; minimum annual rainfall (1913), 308 mm.

[3] Data from L. Weiss, Note sur la répartition mensuelle, journalière et horaire de la pluie à Dakar, in Études météorologiques sur l'Afrique Occidentale Française, Publs. Com. Études Hist. et Sci. Afrique Occidentale Française, Ser. B, No. 3, pp. 71–75, 1937.

The ordinary rains are brought by monsoon winds from the west during the period of maximum insolation in the northern half of the African continent. Throughout the season the air is steamy and the horizon white with water vapor. For a month or so after the rains the sky is cloudy during a considerable part of the daytime, and the humidity remains high.

The dry season is marked by light northerly winds that prevail to an altitude of about a thousand meters. Since they pass over the ocean to reach the peninsula, they bring rather high humidity. Occasionally the dusty harmattan blows out of the east, reducing relative humidity and raising the temperature. It seems to persist above the northerly winds during most of the dry season and perhaps accounts for the whitish blue of the sky. The uppermost air currents move from south to north during the dry months, at about 40 kilometers an hour.[4] The stability of the winds favors aviation. Except for tornadoes, the movement of air at ground level is a breeze rather than a wind.

The annual range of temperature is rarely greater than 6° C., the diurnal variation is commonly 5° (23° to 28° are typical readings). It gets hot as soon as the sun is fairly up and stays hot until near

[3] On the mechanism of the storms see Henry Hubert, Sur les grains orageux dans l'Afrique de l'Ouest, Compt. Rend. Acad. Sci. [Paris], vol. 205, pp. 464–466, 1937; also Les masses d'air de l'Ouest Africain, Ann. Phys. Globe France d'Outre-Mer, vol. 5, pp. 33–64, 1938 (noted in Geogr. Rev., vol. 29, pp. 154–155, 1939).

[4] M. Burcleau, Note sur les courants aériens à Dakar, in Études météorologiques sur l'Afrique Occidentale Française, Publs. Com. Études Hist. et Sci. Afrique Occidentale Française, Ser. B, No. 3, pp. 35–40, 1937.

sunset. In the shade sensible temperature is much lower, except during the rainy season. Then the nights also are stuffy, but for 8 months they are pleasant.

ABORIGINAL LIFE

In this rather unpropitious environment a small African population has been sparsely scattered over the peninsula for untold generations. Presumably the prehistoric inhabitants gained their meager living as did their descendants described by early European travelers—from fishing, supplemented by such cultivation as the short wet season made possible.[5] Diggings show that water supply determined their distribution. The springs at Hann and Rufisque seem to have attracted the densest populations. There water seeps from sand dunes; elsewhere wells must be dug. The Hann site had the further advantage of a surf-free landing for fishing skiffs.

When Europeans undertook settlement in the vicinity, they found numerous hamlets fringing the coast and a smaller number on interior sites at the base of lines of dunes. The people were tall, velvet-black Negroes, a branch of the Wolof. Most of the coastal settlements seem to have used brackish water from marshy backwaters, though some had shallow pits in dunesides. Those cut off by sand or marsh from arable land exchanged their fish for millet raised in interior villages. Oil and wine came from the palms that straggled along the backwaters. The brush and fallen trees furnished firewood. Wattle, basketwork, and thatch were building materials for huts and granaries. All these items except fish were getting scarce by the beginning of the nineteenth century. Millet, planted on one-third of the land, was reported to have been insufficient to support the inhabitants, numbering 10 to 12 thousand.[6]

Today all the villages are modified by the presence of the French-African city of Dakar. Several have been engulfed in the metropolis, to which one, in vanishing, gave its name. Perhaps the fishing villages on the north coast remain much as they were before the Europeans came.

N'Gor is typical of these hamlets of native huts and granaries. It stands on the crest of the continuous line of dunes that have piled up to a height of 8 or 10 meters above the wide white beach (pl. 1, upper left). Among the houses are tiny gardens of squashes and beans, partly protected from drifting sand by mats held upright between stakes (pl. 1, lower left). Fresh water is drawn from wells 3 to 5 meters deep, dug in the front slope of the dunes and walled with

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[5] Pierre Laforgue and Raymond Mauny, Contribution à la préhistoire du Cap-Vert (Sénégal), Bull. Com. Études Hist. et Sci. Afrique Occidentale Française, vol. 21, pp. 523–543, 1938.

[6] Schmalz, quoted by Faure, op. cit., p. 34. In view of the extent of marsh and other wasteland, the crop area was probably smaller; but so was the poplation. The ratio given may be correct.

stones ferried from the offshore islet. The island gives a slight protection from the surf, and behind it the native boats are launched and beached, thus explaining the location of the village on an otherwise uniform coast. When not in use, the skiffs are perched on animal skulls to prevent burial by drifting sand. On the beach a commodious shelter shades the somnolent fishermen during the heat of the day, while in the village above them the women are vigorously threshing and grinding millet and winnowing beans (pl. 1, upper right). This community has some poor millet fields behind the dunes, but it must supplement its supply by exchanging some of its fish.

A different type of village is Ouakam, among baobabs near the Mamelles. There an expanse of low fixed dunes moistens the most extensive arable land west of Sangalkam. Millet, squashes, beans, and a little tree cotton surround the village and yield an agricultural surplus to exchange for fish.

THE EARLY EUROPEAN OCCUPANCE

PORTS OF SENEGAMBIA

With the coming of Europeans, the Cape Verde Peninsula ceased to be merely a sandy offshoot of the African continent and became also the westernmost extension of the coasting route between Europe and East and South Asia. For mariners it marked also the southern terminus of the waterless Sahara coast. The first recorded voyage reported a stop for fresh water at the outlet of seepage from a long line of fixed dunes. This place the Portuguese later christened Rio Fresco (Rufisque) and made it a regular port of call. Food supplies were scarce on the peninsula, and anchorages were subject to storms. Hence for 500 years this neighborhood failed to gain decisive hegemony over its rivals.

Cape Verde stands midway between the two obvious, nature-made avenues for penetrating the Sudan. To the south the Gambia River opens a broad estuary easily entered at all seasons by ships of moderate draft. This was early occupied by the English, and for political reasons has remained little used as a means of access to the hinterland. To the north a lagoon at the mouth of the Senegal River makes a safe harbor; but during the long dry season the shrunken stream can maintain barely enough water for small sailing craft over the bar built across its mouth by a south-setting current. In spite of this handicap, the protected anchorage, an easily defended townsite, and access to the interior by river boat at all seasons made Saint-Louis, the river-mouth port founded by the French, a rival of the Cape Verde district until a generation ago.

Between the Senegal River and Cape Verde the coast is useless for a European port, because of shallow sea, dunes, and heavy surf.

Between Cape Verde and the Gambia River (the so-called Petite Côte) six points have been used for European stations at one time or another. Of the southern three, Kaolack, on a sluggish stream, one of several called locally "the Southern Rivers," has recently become a modest exporting point. The northern three are on or close to the Cape Verde Peninsula and together constitute the Cape Verde Settlements, geographically an inseparable trio.

Rufisque was the first site to attract attention, and its career has included brief periods of prosperity from the mid-fifteenth century to the 1920's. Well supplied with fresh water, it lies in the curve of the tombolo bar and thus is sheltered from the northerly winds that prevail during much of the year, though it is exposed to the stormier winds of the rainy season. The water is shallow, only 3 fathoms at 700 meters from shore. All goods must be lightered and, even though long piers reach beyond the surf, cargoes are frequently damaged by salt water. Both the port and the town are now moribund.

THE ISLAND OF GORÉE

Under the lee of the cliffed hook of the peninsula a considerable body of water is free from the surf that beats incessantly on the rest of the coast. The high headlands enclose roads in which the water is generally quiet, and their steep slopes are associated with deep water fairly close inshore. These advantages disappear with the onset of the southeaster tornadoes and are diminished throughout the rainy season. Then the west side of the island of Gorée offers the least unsafe anchorage. In ordinary times the tiny cove, which faces northeast, offers the same shelter as the adjacent peninsular shore and it is easy to sail out of when a tornado impends.

Other advantages of the island are not obvious. It is only 850 meters long and 300 meters wide in the widest part. A quarter of its 16 hectares is a bare, basalt mesa, 30 meters high. The remainder is a platform a few meters above sea level, leading gently up from the cove to the base of the cliff (fig. 2). It has no source of water except rain, no wood for building or fuel, no sand for masonry, and no arable soil.

The Portuguese, firstcomers, having a choice of ground, made the Cape Verde Islands their headquarters in this region and paid little attention to the Petite Côte. The Dutch were the first to occupy Gorée, and half a century elapsed before they took Rufisque and its neighbors. Their selection of a confined, waterless island for their principal settlement was sound, as is proved by the fact that under subsequent French (and occasionally British) occupation Gorée remained dominant along the Petite Côte for four centuries and at times rivaled Saint-Louis as the leading European post between Gibraltar and Sierra Leone.

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This paradox is explained by the nature of the chief business of West Africa during most of this period. Gorée was, nearly all the time, the most important point in Senegal for the Negro slave trade.[7] For this traffic the island had notable advantages. Habitual forays engendered unceasing warfare between the raiding coastal tribes and their victims of the interior. The European trading companies, in spite of superior weapons, had relatively slight military strength and therefore prized an offshore location. Gorée harbor lies 2.35 kilo-

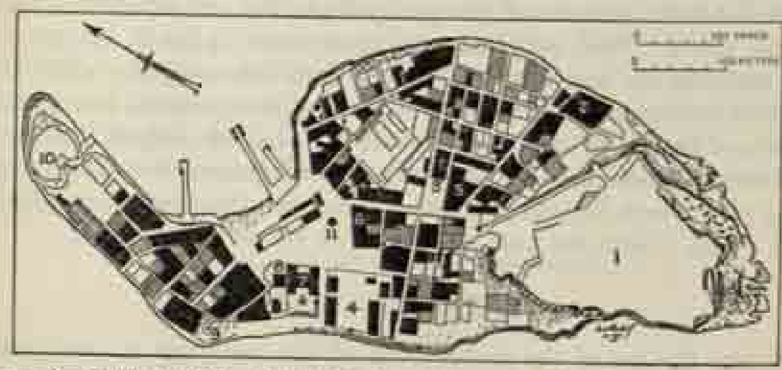

FIGURE 2.—Gorée in 1932. Condition of buildings noted by Sergeant Costel: existing structures, solid; ruined structures, barred; sites of former structures, outlined. Key to principal buildings: 1, fort; 2, barracks; 3, church; 4, hospital; 5, boys' school; 6, normal school; 7, AOF printery; 8, town hall; 9, west battery; 10, north battery; 11, reservoir. (Reduced from map in Gorée, capital déchue, by Robert Gaffiot.)

meters off Dakar Point, close enough for canoes loaded with slaves to be brought out conveniently under surveillance by batteries flanking the cove. The shark-infested waters denied escape to imprisoned Negroes. The flat-topped cliff lent itself to fortification against trade rivals from Europe sailing under enemy flags. Transfer of slaves and the small volume of minor exports and imports between continent and island entailed only a somewhat longer lighterage than at any other ports of the Petite Côte.

The relations of island to continent were but slightly affected by successive changes in political affiliation, because Gorée and the Petite Côte always went together. That the Cape Verde area was an important element in the new world pattern being laid out as a result of the discoveries and the creation of colonial empires is indicated by repeated change of hands.

More important for the fortunes of the island was its rivalry for the seat of French colonial administration in Senegal. At times it was supreme. Generally it administered the Petite Côte and the Southern Rivers. Occasionally it was subject to Saint-Louis.

[7] Robert Gaffiot, Gorée, capitale déchue. Paris, 1933.

The town was built to accommodate trade and administration, and its structures express their functions. All the buildings are constructed of masonry, and most of them are made of rough stones or rubble concealed by smooth stucco. All the larger ones have capacious cisterns in the basement, to catch and store the run-off from the roof. The most conspicuous structures were designed for administration. A fort looms on the mesa, and batteries flank the lower ground. There are also barracks, hospital, church, and buildings for local and colony administration. The rest of the buildings with any pretension were planned to meet the peculiar needs of the slave trade. The ground floor is divided into cells where the captives were locked awaiting deportation. On the floor above are the offices of the trading firm and living quarters for the personnel. From a number of houses balconies overlook the street. Supplementary quarters for the household are on the third story when there is one. All rooms are ranged about a patio, in which a tree or two may be growing.

In the heyday of the place all available space was utilized. The solid blocks of buildings interfered with the breezes that swept across the island from the surrounding sea. The streets, narrow lanes though they are, were reported as "furnaces between ten o'clock and five."[8] During the last half century, as the population decreased, buildings were abandoned. Today at least half of the land formerly occupied by buildings and patios either is open or stands as unroofed yards surrounded by ruined walls. This has opened the town to currents of air, which mitigate the heat. The razing of dilapidated buildings has been enforced, especially after epidemics, because the tight-packed town with its numerous cisterns has always been a potential center of infection.

More than once the little white colony has moved temporarily to the peninsula when epidemics have broken out. The first siege of yellow fever occurred about 1779. It so demoralized the community that the forts were demolished, the survivors went to French Guiana, and the governor removed to Saint-Louis.[9] In addition to soldiers manning the fort, only 200 persons inhabit the island now, and a high percentage of them are aged. The estimate for peak population is 6,000, a figure for which no date is given but which presumably refers to the 1830's. Three-fourths to four-fifths of them were captives.

Today Gorée is a sleepy, ruined settlement, 40 minutes from Dakar by the launch that makes three or four trips daily. The printery for the colonial government is housed in the building used in prosperous days by the governors. A normal school and a boys' school attract daily a little spate of pupils from Dakar. The small church is too

[8] Alfred Marche, Trois voyages dans l'Afrique Occidentale, p. 5. Paris, 1879.

[9] Gaffiot, op. cit., pp. 75–76.

to France. Six tried again, on what they hoped was more favorable terrain at Bel Air, but they died of fever.[12]

MODERN EUROPEAN OCCUPANCE

THE ESTABLISHMENT OF DAKAR

At the beginning of 1857 a letter from the colonial minister authorized the Chief of the Naval Division at Gorée to set up a military post at Dakar and to build a commercial city there.[13] The French authorities landed a force of marines and took formal possession on the feast of Ramadan. Each local headman was given a French flag to fly over his hut, thus to identify the occupation with the current atmosphere of rejoicing. All payments for water, wood, and building materials were thenceforth abrogated.

A fort was built on Dakar Point. Several inhabitants of Gorée moved there to build houses under its protection and to cultivate small gardens. The Messageries Maritimes (then Messageries Impériales) agreed with the French Government to have its ships stop on a monthly service between Bordeaux and Rio de Janeiro, the Cape being about halfway. The next year the company bought land under the point for a coal park and demanded that the government construct a breakwater, necessary during the rainy season to complete the protection afforded by the cove. A curate took up residence. The barracks were manned by a detachment of troops under sentence for infractions of discipline. Besides overawing the indigenes, these soldier-prisoners maintained a garden and orchard at Hann. A street plan for the prospective city was adopted.

For a quarter of a century after these beginnings Dakar made little progress. In the 1870's Gorée felt a new wave of prosperity, after a decline that had resulted from the abolition of its slave trade. Its population numbered more than 3,000. The headquarters of the commercial houses remained there, and the island continued to administer the Petite Côte. Dakar, in contrast, had only a dozen or fifteen small merchants, whose principal business was that of dramshops. The few Europeans and a somewhat larger number of Europeanized Africans lived in nondescript dwellings, generally of wood, scattered among the huts and compounds of the aboriginal villagers.

Whatever commercial business migrated to the peninsula settled at Rufisque. A decade before the founding of Dakar the first peanuts had been raised behind Rufisque in calcareous sand moistened from a line of dunes. The crop proved admirably suited to the soil and

[12] Faure, op. cit., p. 21; Gaffiot, op. cit., pp. 132–135. Accounts do not agree, even as to site of settlement; but the picture is essentially true for the time and place.
[13] Quoted in Faure, op. cit., p. 118.

climate. Beginning with 70 tons exported to France in 1849, Rufisque sent 3,000 in 1853. For seven decades the name of the port remained synonymous with Senegal peanuts, trade in which replaced traffic in Negroes as the leading export of the colony. To handle the business, large warheouses were built, and in time five piers extended through the surf. A gridiron pattern of sand-drifted streets, laid out earlier, was extended and in considerable part built up. Counting-houses of cut stone and residences of masonry with balconies occupy the center. Beyond are cabins of Africans, largely built of wood.

As the peanut-growing area pushed inland, Rufisque had to share its exporting business with towns on the Southern Rivers. Dakar, 25 kilometers farther from the fields along a track heavy with sand, got none of it. The locational advantage of Rufisque seemed to be so unassailable by economic weapons that the founder of Dakar proposed to suppress its trade by governmental purchase of the warehouses and removal to the new town. When, years later, Dakar began to export peanuts and, after another interval, outstripped its rival, the change resulted from improvements in transportation. Today most of the Rufisque warehouses stand empty, its piers are breaking up, and the trading firms have voluntarily abandoned their offices for new ones in Dakar.

During its first stage of occupance as a European station, Dakar had little to do with its remote and inaccessible hinterland. Rather, its life hinged on the location of the peninsula and the character of the anchorage with reference to vessels passing along the West African coast.

Any of the coves in the lee of the peninsula required a breakwater to be a safe anchorage during the rainy season. Gorée harbor was strongly supported by vested interests in the town; but small size and the limitations of the island were no longer offset by personal security, when once the whole of Senegal had been made safe by French arms.[14] Bernard Cove had 3 fathoms of water only 200 meters offshore, but the breakwater would have to be built into water 6 fathoms deep. The high land gave complete shelter against west and north winds, but the steep shore left no low ground for a townsite (pl. 3, upper left). Dakar Cove had ineffective protection from the northeast, but a breakwater in shallow water would deflect waves kicked up by east and south winds. The relatively low shore was suitable for a port. The tide range in the entire Bight of Gorée is less than 1 meter and therefore presented no problem.

Dakar was selected, and the government undertook to run a breakwater from the coal park of the Messageries Maritimes, using the soldier-prisoners and unskilled enlisted Africans. More than 200

[14] For the pacification see General Faidherbe, Le Sénégal. Paris, 1889.

white men were enrolled, but illness reduced the average number at work to about a hundred. When 300 meters long, the pier reached water only 5–6 meters deep. Coaling still had to be done by lighter, and the Messageries Maritimes continued to use St. Vincent, Cape Verde Islands, as its port of call. A second jetty, running north-northeast from the extremity of Dakar Point, reached a depth of 10 meters at 330 meters and withstood the storms of the rainy season of 1866. The port of call was then transferred to Dakar, and the shipping company built a house near its quay for its representative, who was expected to put up official and other distinguished travelers during the 24 hours their boat remained in port for coaling. Although shelter from the northeast was still inadequate, the harbor received little further alteration for another generation.

By the time the jetty was finished, the Cape had been supplied with suitable lights, and shipwrecks decreased. A lighthouse to mark the Cape was built on the western, higher Mamelle, supplemented by a beacon on the outermost of the reeflike islands off Almadies Point.

The official town plan was dictated by considerations of health and commerce.[15] The site was studded with low dunes, from which a small amount of potable water could be obtained; cisterns were also used. A cemetery (much in demand on this unhealthful coast) was begun well away from the habitations. The gridiron pattern usual in French colonial foundations was adopted, with orientation to compass directions, to take advantage of the alternately north and south prevalent breezes. Its south edge was a street made broad for sanitary reasons, punctuated midway by a plaza intended for the church. Land facing the plaza was reserved for administration buildings. Beyond the wide street stood the military quarters, an extension of the battery on Dakar Point. (Fig. 3.)

The water front made a shallow S. Behind it the ground rose irregularly to a plain. A belt 81 meters wide along the shore, on which no new construction was permitted, was reserved for public use. Conveniently central to the civil and military establishments and to the port was the market place.

With the change of a few street names, this layout has become the core of the later city. At first population grew slowly. Superiority of the port to that of bar-choked Saint-Louis led a private company to build a railroad connecting the two, opened in 1885. Its terminus was on the harbor side, at the north base of the high ground where the early town stood. It stirred the stagnant town to its first real animation. Gum arabic and other light produce of the Senegal River area came in to take advantage of the regular sailings. A few peanuts

[15] Pinet-Laprade (founder of the city and originator of the plan) to the Governor of Senegal, Aug. 24, 1859. Quoted in Faure, op. cit., pp. 146 ff.

came in past Rufisque, but high freight rates and paucity of wharfage left the older port well in the lead.

RUDIMENTARY CAPITAL AND PORT

The second stage of European occupance was initiated by stirring events at about the turn of the century. Senegal then became the

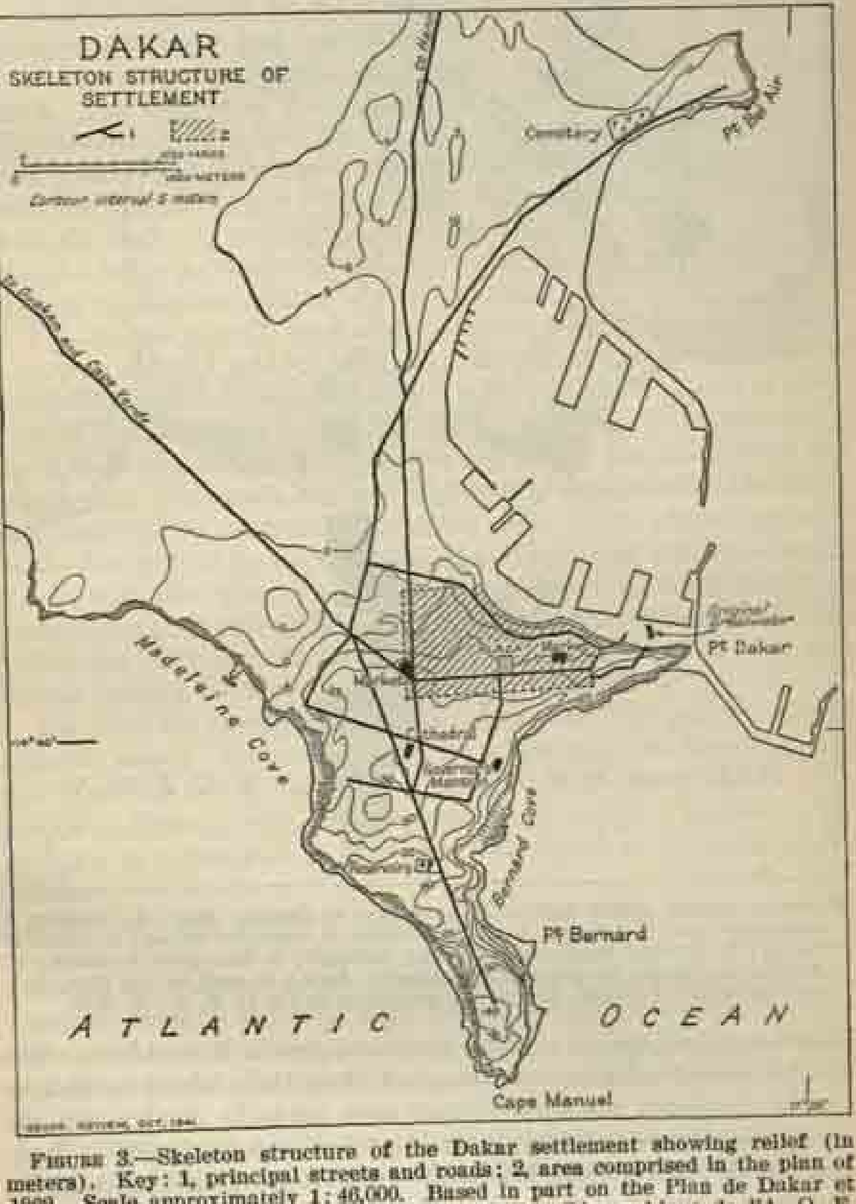

FIGURE 3.—Skeleton structure of the Dakar settlement showing relief (in meters). Key: 1, principal streets and roads; 2, area comprised in the plan of 1862. Scale approximately 1: 46,000. Based in part on the Plan de Dakar et environs, 1: 10,000, d'après photo-aérienne Service Géographique de l'A. O. F.

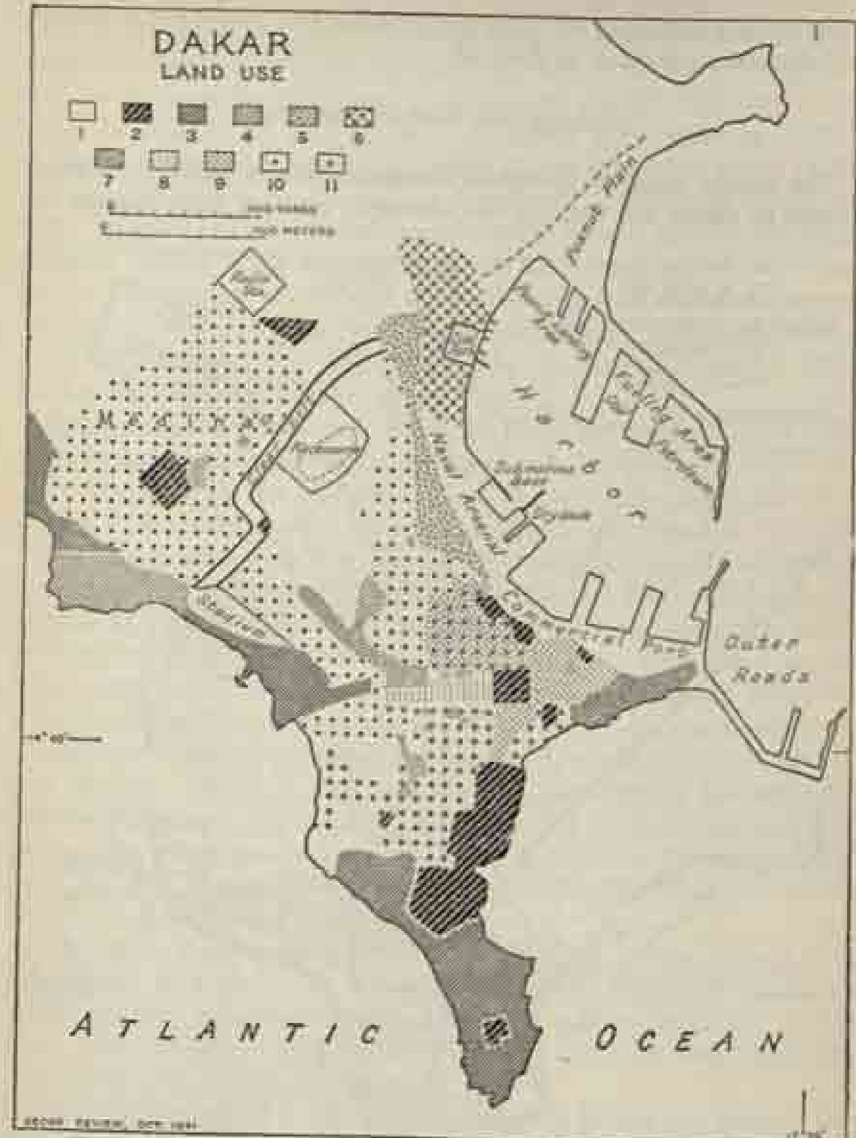

FIGURE 4.—Areal differentiation in land use at Dakar. Key: 1, unbuilt; 2, administration; 3, defense; 4, public services; 5, communications; 6, manufacturing; 7, African business; 8, Syrian business; 9, European business; 10, African residence; 11, European residence. Based in part on the Plan de la ville de Dakar, 1:10,000, Service Géographique de l'A. O. F., Paris, 1936.

base for active expansion of the French empire in West Africa. The several coastal colonies were cemented along their inland borders by newly conquered territory. Plans were made to amalgamate old holdings and new as l'Afrique Occidentale Française (AOF). Senegal was the easiest nexus between the outside world and much of the territory acquired at that time. Saint-Louis, traditional capital of

Senegal, was designated as the seat of the new supergovernment, in addition to administering both Senegal and Mauritania as subcolonies.

Dakar continued to make inroads on the business of Saint-Louis, and after a few years the government of the AOF was transferred to the rising town. Pending the construction of necessary buildings, the administration was housed at Gorée and gave the island a brief afterglow of authority.

As at its inception 40 years earlier, the expansion of Dakar was planned with health and commerce as ruling considerations. (Fig. 4.)

The capacity of the harbor was greatly enlarged between 1898 and 1912. The jetty was prolonged to a total length of 530 meters. Thenceforth it was called the South Jetty, to distinguish it from the new North Jetty, a breakwater projected at right angles to the coast near the base of Bel Air Point, though not until years later connected with the land. It reached a point 2,080 meters from shore. Between the two jetties an easily navigated opening was left, 250 meters wide. The water thus enclosed covers 225 hectares.

The sinuous water front was straightened with dredgings from the harbor, making a broad, level space for railroad tracks and roads to serve the port and for warehouses and other port buildings. The north half of the new frontage was reserved for a naval arsenal, with a dry dock to handle ships of 10,000 tons and a base for submarines and destroyers. The south half was improved to accommodate the growing trade by two moles 300 meters long and a third as broad, oriented in the direction of the prevalent winds and equipped with warehouses. These, with the intervening quays alongshore, total 2,200 meters of wharfside (pl. 2, lower left). Running water was made available for ships, but coaling continued to be done by long lines of male and female porters, because of the cheapness of their labor.

The need for providing water for ships was only part of a more insistent demand for sanitation of the whole city. In favored places north of the town, dunes were systematically honeycombed with channels, through which water collected in sumps. Thence it was pumped to a reservoir in town and distributed at hydrants in the streets.

Other sanitary measures begun at this time were calculated to reduce the menace of mosquitoes. Ravines in the town were filled. Marshes and backwaters for 20 kilometers out were drained by cutting channels through the sand bars that separated them from the sea. Brush was cut to eliminate breeding places, and plantings of eucalyptus and filaos on low places were made over the whole headland, to lower the water table. Harbor improvements and the installation of the government of the AOF were sure to bring increased population. In anticipation, the original plat of the city was quintupled by new

layouts to the south and west. In these sections the gridiron was abandoned for a freer pattern, shot through with diagonal avenues, making "stars" and "round points" in the manner of Paris. Some of the new main streets had been country roads. Others included a broad avenue leading from the original plaza to and beyond the governor's mansion, an imposing edifice of this period standing in a park on the breezy bluff above Bernard Cove (pl. 3, upper left).

The extended city incorporated two or three African villages; and for some years the thatched huts of the indigenes, close-clustered in asymmetrical African fashion, continued to mingle conspicuously with the regular blocks of masonry houses put up by the government for its officials or by the trading and shipping companies for their administrators and with the less pretentious frame habitations of humbler white people. In places the commingling still exists.

During this time most of the remaining Gorée merchants moved to Dakar. In the first decade of the new century port business increased threefold. External connections improved. Additional shipping companies made the place a port of call. A cable to France was laid. A direct railroad line to connect with the upper Niger River was begun.

DAKAR COME OF AGE

The first World War put a stop to government expeditures on Dakar and checked nearly all development. Afterwards a new stage of occupance was inaugurated by a long series of public works accompanied by extensive private undertakings.

WATER SUPPLY AND OTHER SANITATION

In all tropical African stations the safeguarding of health is the most important and difficult obligation of the European government. In semiarid and ever-growing Dakar shortage of water has continuously complicated the problems of sanitation and health. In the hope of finding an assured supply a thorough hydrographic survey of the peninsula was made. No deep-seated sources were discovered. Instead, the dune-tapping system was extended. At Hann, on which Gorée had always depended for its supplementary supply, more water was found at a depth of 30 meters. An even more copious store was disclosed behind the village, along a line of rather high fixed dunes, on one of which stands Fort B. These dune sponges are about 6 kilometers from Dakar. Twenty kilometers out, at M'Bao, a similar site has been developed and tied into the system. Additional supplies exist in the dunes that run from Rufisque northeast to Sangalkam. These are used only to serve Rufisque. Neolithic man, African indigenes, passing European ships, and the European settle-

ments of the district—all have been dependent on the dunes for their water.

Water from the city supply is available for irrigating market gardens at M'Bao, Ouakam, and the outskirts of Dakar. These settlements and Tiaroye are served by hydrants in the streets. In Dakar itself water may also be laid on in buildings. The port is supplied through a separate pressure line, with a reservoir holding 3,600 cubic meters, a 5-day supply. In the high part of the city are six reservoirs for city and suburbs, with a capacity of 7,400 cubic meters, a 2-day supply.[18]

Potable water is too precious to use for fire hydrants or for flushing streets and sewers. These services are provided by water pumped from Bernard Cove into a reservoir holding 3,000 cubic meters (fig. 3). Regular flushing of the streets sweeps out the larvae of mosquitoes along with dirt and so renders a twofold health service.

The sewer system is integral with the water system. It includes special collectors for storm waters. Public latrines are distributed throughout the municipality, and at least four public shower baths are available. The African population take full advantage of opportunities to bathe and to wash their garments, whether in buildings provided for the purpose or at street hydrants or in the harbor or other calm waters. As elsewhere in tropical Africa, the indigenes need no coercion to bathe. Garbage and other waste is collected twice a day and burned in a city incinerator.

As in every other tropical African center, there are separate hospitals for Europeans and Africans. Specialization has extended to include hospitals for the military and civilians, a maternity hospital for Africans, and, far out on Cape Manuel, a leprosery. Numerous clinics are distributed over the city and suburbs. The medical service is capped by a school of medicine.

SEGREGATION AND POPULATION

All these sanitary measures would have been less effective if steps had not already been taken to segregate the European inhabitants from the African. Much of the increase in population has been freshly recruited from the bush. These indigenes, and even a good many who have been long exposed to European sanitary practices, live without regard for standards necessary in urban agglomerations. Thereby they menace the health of their neighbors, particularly Europeans, who are less immune to tropical diseases than Africans. In the commingled community of Dakar occasional epidemics of yellow fever have taken heavy toll of both races. Less spectacular but more serious have been

[18] Georges Péter, L'effort français au Sénégal, pp. 321–322. Paris, 1933.

the ever-present scourges of malaria and dysentery, which strike outlanders down, often with fatal results, while touching indigenes as hardly more than uncomfortable ailments. In 1914 bubonic plague was added to the considerable list of infectious diseases of local origin. Although it attacked Africans almost exclusively, their careless attitude toward sanitation made eradication difficult.

To eliminate African compounds within the European city, an African suburb, Médina, was laid out in rigid gridiron pattern, with blocks smaller and streets wider than those of the early plat of Dakar. It is separated from the older town by an unbuilt reserved clear belt 900 meters wide, as well as by a racecourse and a stadium. Africans resident in Dakar have been encouraged to move to Médina by gift of land and aid in financing housebuilding. The place has grown fast. Today it contains more than half the total population of Dakar. Most of the habitations are thatched huts, a good many are wooden cabins with tile roofs, and a few are of masonry.

Some 20,000 Africans still live in Dakar proper. In the northwest quadrant Africans occupy nearly all the land, and many are interspersed among Europeans in the older sections (fig. 4). Their houses may be made of wattle, boards, mats, flattened gasoline tins, adobe, frame, and even masonry. Many are tile-roofed. In size they range from huts to commodious houses (pl. 2, upper right).

The strictly European residential quarters on the high ground are spacious and airy. There the higher bureaucracy, some of the foreign consuls, and many leading executives of business firms live in villas hung with bougainvillaea and set in tree-shaded grounds. The houses are agreeably adapted to the climate, being shallow, with wide windows opening on verandas or terraces shaded by overhanging roofs. Most of them have been built by the government or company whose representatives occupy them. This has been necessary to house a community who may make Dakar their residence for few or many years but who invariably spend long leaves in France at frequent intervals.

Dakar, with its suburbs, forms a unit of 158 square kilometers, in which the population density is some 350 to a square kilometer. It is the largest native city in the area, thanks to opportunities for work of all kinds. At the same time the ratio of Europeans to Africans is high, 15 to 100, as compared with a tenth as many in Saint-Louis, a more nearly typical coast city. Half the Europeans in the AOF—some 6,500—reside in Dakar. The percentage of women and children is far higher than in any other place in West Africa. The African population is likewise exceptional in being made up of people from all over Senegal, and indeed the entire AOF. Contrasting physical types, accentuated by a wide range of dress, make the streets a colorful pageant in the animated hours of early morning and late afternoon.

TABLE 2.—*Population growth of Dakar*[1]

1878	1,556	1924	[3]40,000
1891	8,737	1931	[4]53,982
1904	18,477	1936	[5]92,634
1914	[2]23,833		

[1] Data from various sources. Censuses are taken on July 1, when the population is reduced from the dry-season figure: many Europeans have returned home to escape the rains; many Africans are at work in the fields of their native villages during the rainy season.

[2] 2,772, white civilians; 1,242, white army and navy people.

[3] 3,000, outlanders (estimate).

[4] 4,989, French; 1,570, other outlanders, mostly Syrians, Lebanese, and Moroccans. Figures for Gorée included.

[5] Dakar and dependencies, including nearby villages.

The outer garment of the men is a voluminous robe with low neck and short sleeves, in white, blue, or yellow, or, occasionally, brown, black, or mixed colors. For manual labor this is doffed, exposing a knee-length, sleeveless union suit. The headdress may be a red or black fez, a knit toque, a cone of straw, or a tropical helmet in imitation of the Europeans. An amulet is always hung around the neck, and armlets are common ornaments. The women wear a long, full-skirted dress. All who can afford it have gold earrings, and many braid gold coins into their tiny pigtails. The whole elaborate coiffure is capped with a bright turban.

AREAL DIFFERENTIATION OF FUNCTIONS

Areal segregation of races is common in West Africa. Separation of functions is rare and nowhere, except in Dakar, more than incipient.

Because the city came into existence to serve French colonial interests, much land was taken at the outset for administration, defense, and other public services. For these services are reserved nearly the whole harbor front, the remainder of the coast line with two exceptions, the surroundings of the plaza, a central area in Médina, and more than a dozen scattered sites. Defense occupies Points Dakar and Bel Air, most of Cape Manuel, an area of high ground overlooking the open ocean, and range for target practice along the shore northwest of Médina. Hospitals overlook much of Bernard Cove. The government of the AOF clusters principally about the governor's mansion. Local government buildings are at the plaza (pl. 3, lower) or on the original water-front terrace (pl. 3, upper right), except the residency in the center of Médina.

Public services less official than defense and administration are more scattered. Lower schools are dotted about; the high school (*lycée*) is on the west side of town. Where the new residential quarter for Europeans is pushing into the nondescript African purlieus, a huge cathedral has been completed recently in a style

reminiscent of both Byzantine and Moorish architecture (pl. 2, lower right). The mosques are small and are placed unostentatiously in back streets (most of the small spots symbolized as "services"). There are perhaps 10 to 12 thousand Catholics, including a thousand Syrians.

The public markets handle all the perishable foodstuffs. For Europeans a market house has been erected on the site of the original market place in the old town (pl. 4, upper left). All but one or two of the vendors are Africans. Many shoppers are African servants, who mingle with European women making their own selection in thrifty French tradition. The other covered market, a huge, two-level building at the nexus of Syrian and African business districts, is entirely African. The lower floor is unfurnished, and the market women heap their wares in little piles on the floor or in calabashes, or overflow into surrounding streets. There are also two large, open-air markets in Médina. Scattered trees or awnings shade the vendors, at least during the moister half of the year (pl. 4, lower left).

All the markets carry the same range of goods. Vegetables come from the gardens and nearby village patches. They are abundant and varied during and after the rainy season but dwindle as the sandy plains become desiccated. Fruits are less common. To local mangoes and papayas are added imports—bananas from French colonies farther south, oranges from Brazil, apples from Argentina. Local fish appear, lightly smoked or sun-dried, and include herring, sardines, and achovies, and also several tropical species. Meat comes down from the interior and is killed in the local abattoir for immediate sale, refrigeration being uncommon. The covered markets close about noon, but the others do business all day.

Where private holding makes the use of land competitive, differentiation of functions has largely supplanted the original conglomeration. Vestiges of the older order, particularly on back streets, emphasize the change toward the pattern of Occidental, middle-latitude cities and away from the traditional town of the low-latitude African coast.[17]

The commercial core is an areal unit but is sharply divided into European, Syrian, and African sections. The earliest business streets led up from the passenger wharf to the 15-meter level on which the town started. These are now devoted to shipping offices, banks, and curio shops. They tie into the wide avenue that marks the south edge of the original planned town and leads to the central plaza. This avenue and the later and still broader one that leads from the

[17] For a description of the earlier stage of undifferentiated occupance see J. Rouch, Sur les côtes du Sénégal et de la Guinée: Voyage du "Chevigné." Paris, 1925.

plaza up to the governor's mansion have become the principal shopping thoroughfares. Between the old town and the plaza are bookstores, a music store, a pastry shop, a grocery, and several barbers, but large wine stores dominate. Between the plaza and the "plateau" are shops for women's wear, shoes, novelties, stationery, and refrigerators, besides pharmacies, photographic studios, and a cinema. Besides these, large stores carry varied merchandise. In kind, their inventory is much like that of traditional African *comptoirs;* but in character they are European department stores, with show windows, well-defined sections for different articles, and emphasis on quality and fashion. Many shops are branches of French firms. Others are of local origin—another evidence of commercial progressiveness.

These streets catering to the carriage trade are somewhat somnolent, particularly during the sunny hours from 10 until 4, though the shops close for only a 2- or 3-hour siesta. In sharp contrast is the extension of the older main street beyond the plaza, where it changes both its name and its character. The little, open-front shops of this section are owned and operated mainly by Syrians and North Africans. They cater to the indigenes, who enliven the street with their billowing costumes and incessant movement and chatter. "Cloths" and other "Manchester goods" sold in every West African town constitute the bulk of the stock; and nearly every place of business carries a little of everything, including staple groceries and dried codfish. Some differentiation appears in the separate wineshops (successors to the dramshops of old Dakar) and in stress here and there on French novelties. The shopkeepers live on the premises, a custom formerly universal in Dakar but becoming uncommon among European merchants. Half a dozen blocks along this street is the corner of the original town plat, now the principal traffic focus of the city and site of the principal market house. Beyond, shops run by Africans extend through an African quarter toward Médina. Most of these are drygoods stores, where men busily sew the dresses worn by both sexes.

Market gardens are cultivated on reclaimed coastal marshes or on sand dunes where the soil is moist, and some are irrigated. They are worked by men clad in breechclouts. Most of the fresh produce finds its way to European dining rooms. The Africans are consuming more and more imported food, chiefly rice from the middle Niger Basin and Indochina and dried fish taken by Bretons on the Icelandic or Grand Banks.

In contrast with merchandising, there is scarcely any manufacturing in the European sense. The waterworks, the electric plant, a brewery for beer and soft drinks, two refrigerating plants, and a laundry make up the list. All stand near the north end of the harbor,

adjacent to the coal park, on level land between railroad and water front. Small stone quarries and a brickkiln provide building material as needed.

Most of the manufacturing is handicraft. Dressmaking with the aid of American sewing machines occupies hundreds of men (no women). Carpenters make furniture for local use out of the handsome African cabinet woods. Marabouts contrive amulets. A few jewelers still fashion the filagree ornaments prized by the women. Competition by machine-made goods from Europe has all but driven out the weaving, dyeing, basketmaking, tanning, and steelwork that flourished before the first World War, utilizing native materials to satisfy native needs. Some 8,000 men gain a livelihood from manufacturing and handicrafts.

Race segregation and the clustering of business have set up a diurnal rhythm of movement, on foot and in a fleet of nondescript motor vehicles that ply as busses. Market folk bring in their produce before dawn. In the cool of the early morning a tide of workmen and domestics (all male) from African suburbs and villages farther afield flows into the port, the factory district, the artisans' street, and the European homes. Clerks in the offices scatter through the commercial and official sections. All except the domestics return home about 6 p. m. Oiled macadam roads connecting all the villages, and the 28 kilometers of principal streets, facilitate this movement. Road building has been costly, because of shifting sand and the lack of laterite, handy road metal in many parts of tropical Africa.

THE PORT

Areal differentiation in the port is even more marked than in the city. Except for its political function, Dakar is the creature of its port. The chief commercial business combines importing and exporting with servicing ships that call; the marine arsenal, covering 16 hectares, is the largest factory in town. Both these functions greatly expanded between the two World Wars.

Direct meter-gauge rail connection 1,291 kilometers into the interior was made in 1923. Since this date Dakar has handled nearly all the varied imports of Senegal and the French Sudan. Exports have increased, but less signally. Aside from peanuts, 78 to 80 percent of the commerce of Senegal and the French Sudan passes through Dakar.

The dominant export crop of the hinterland is peanuts, grown in the short rainy season and marketed from November until June. During the early months of each dry season, great heaps of bags and hills of unbagged, unshelled nuts accumulate at the peanut ports (pl. 4, lower right), taxing their resources. The lesser crops come in at the

same time. Ports 60 to 120 kilometers upstream at navigation head on the Southern Rivers are close to the fields; but ships cannot take on full loads because of shallow bars across the river mouths. They must therefore call also at the peninsula to complete lading from stores sent down by rail. At Rufisque lighterage subjects the crop to damage. Kaolack, the only accessible river port on a railroad (a branch of the state-owned line), has the advantage of Dakar in mileage and, formerly, also in rates. Since purchase by the state of the Dakar-Saint-Louis line in 1932, the rates are proportionate to the mileage, and Dakar has increased its shipments. Nevertheless, Kaolack continues to lead in exports of peanuts, shipping nearly half the crop of the western AOF.

Recently the North Jetty has been tied to the base of Point Bel Air, and dredgings have added a triangle of 15 hectares with 600 meters of harbor front. This land, christened "Peanut Plain," is served by rails. Ships can be loaded alongside, as well as in mid-harbor. Peanuts are loaded by hand, because the bulk of the crop arrives in bags. These facilities have freed the older port for general business. A half mole has been affixed to the South Jetty, increasing wharfage in that section.

The first business of the port is fueling ships in transit. This is now handled alongside and by lighters just inside the North Jetty. Coal is brought by ships from Europe coming for peanuts, and the coaling mole and basin, equipped with cranes and pontoon derricks, are next to the area where peanuts are loaded. Diesel and oil-burning ships have caused coal imports to fall off and petroleum to rise more than correspondingly. The end of the jetty is piped for petroleum, which is also available by lighter. During the rainy season, business with the hinterland ebbs—exports practically cease. At this season the backlog of shipping in transit keeps the port going. To increase the business, the harbor has been continuously dredged deeper since 1924. The fueling area is now 5½ fathoms deep; alongside some moles are 5 fathoms of water, at others 4½.

Recent port statistics for Dakar are not available. About 1933 or 1934 more than a million tons of merchandise (exclusive of bunkerage fuel) was carried on 2,250 ships. Passengers numbered 15,000 entering and leaving. The chief commodities imported were petroleum and coal, 612,000 tons and 213,000 tons respectively (including bunkerage); in foodstuffs, rice led with 16,000 tons, followed by wheat, sugar, and wines. Of exports, peanuts were far in the lead with 310,000 metric tons, followed by gum arabic (4,000 tons) and sisal.

THE "AFRICAN GIBRALTAR"

The improvements have increased the value of the port as a naval base, particularly for submarines. In 1938 work was set afoot to make

a station of the first class. So vigorously was it prosecuted that it was nearing completion when the war broke out. The submarine base has been improved. A floating dock supplements the fixed dry dock. Storage for petroleum has been enlarged by building concealed tanks.[18]

Still more ambitious has been the construction of an outer roads by building a new jetty, 2,500 meters long, southeastward from Dakar Point. It extends into 8 fathoms of water and provides anchorage calm enough for large ships, particularly war vessels. Craft of 35,000 tons can ride there out of reach of tornadoes, though not well protected from the choppy waves of the dry season. Since the outbreak of hostilities the entrance to the anchorage and harbor has been closed with a boom. Fifteen kilometers of meter-gauge rails and six kilometers of roads serve the port.

Associated with naval expansion has been reinforcement of the land fortifications on Gorée, Point Bel Air, and Cape Manuel. Warehouses on the Peanut Plain and a seaplane port in Hann Cove under Bel Air Point can be used for warplanes, supplementing the naval and land defense. The place is now a stronghold; it has been called "the African Gibraltar."

A WORLD FOCUS

Dakar owes its cosmopolitan character to its function as a contact point. Location makes it a convenient port of call for all ships plying between the North and the South Atlantic, except those in the American coasting traffic. Besides French lines in the South American and West African trade, one connecting France and Morocco has extended its sailings from Casablanca to Dakar, twice as far from the home port. (Marseilles and Bordeaux are the French termini.)[19] All ships plying regularly past the Cape call, and many tramps find it a good place to drop coal or pick up peanuts.

Location at one end of the waist of the Atlantic has led to the creation of a powerful naval base. For the same reason Dakar is the point of departure for the oldest transatlantic air line. A weekly postal plane links Paris and Rio de Janeiro, each of which is about 48 hours from Dakar. Two fields are used: for seaplanes crossing the ocean, at Hann Cove with facilities on Point Bel Air; for land planes in the European traffic, on level land near Ouakam. Dakar is likewise the terminus of an air route that traverses the length of the Sudan.

Incidental to its world-wide sea and air routes, the place has been linked by cable to Brazil, to the Guinea coast of Africa, and to Brest,

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[18] Herman Röckel, Dakar, das Zentrum der seestrategischen Stellung Frankreichs am Mittleren Atlantik. Zeitschr. Geopolitik, vol. 17, pp. 419–426, 1940.

[19] For a list of lines calling regularly at Dakar see Charles Morazé, Dakar. Ann. de Géogr., vol. 45, pp. 607–631, reference on pp. 612–613, 1936.

France. A radio station at the edge of Médina is the wireless nexus between French West Africa and the outside world.

Dakar was selected to be capital of the AOF because it had the harbor with greatest possibilities in the part of the colony nearest to France by sea and because the peninsular climate is drier and more tempered by sea breezes than that of any competitive point. As capital, it was made the anteroom and outlet for the extensive hinterland of the open Sudan, a country easily traversed throughout the dry season and favorable to low-cost railroad construction and maintenance. For passengers there is daily rail service to Saint-Louis and semiweekly trains with sleepers to Bamako, near the interior end of the line. Not many roads passable during the rains have been built; but dry-weather roads penetrate all the back country and make connection with every one of the constituent colonies of the AOF. Dakar is the ganglion of 25,000 kilometers of telegraph and telephone wire, reaching to the far parts of its territory.

The recent rise of a city in a district hitherto sparsely settled and rural has brought in a diverse population, which is not yet amalgamated. Africans mingle with Europeans on the streets and speak French when necessary but preserve their native language and dress and perhaps return home seasonally or to end their days. Syrians and North Africans bring their families but plan to return when they have made a competence. They are not fully accepted in the European society and hold themselves somewhat aloof from the indigenes.

The Europeans are still less rooted. It is the French way to create the semblance of a European city (one which happens to have much the flavor of a provincial capital in France). When the working day is over, the white population forgathers at the cafés, on the business streets, and in the spacious and airy hotel dining rooms. Dining in public is even more usual than in Paris. A cabaret in the most fashionable hotel offers entertainment by actors and singers from Paris. A weekly newspaper carries the local news. In reality, the resemblance to European life is superficial. All Europeans come out for "tours of duty" lasting from 2 to 4 years. After a long holiday in France, they may or may not return to Dakar. On retirement they return "home" to end their days. Few of the younger men are married. The wives of the others often spend the rainy season in France. Many families leave their children in Europe, though the gamut of public education up to the university is available in Dakar, alone among West African stations. Of the outlanders 65 percent are men, 25 percent women, and 10 percent children.

The roots of a large part of the populace, of whatever color, are thrust in soil outside the Cape Verde Peninsula. In the spiritual as well as in the geographic sense, Dakar is a port of call.

[illegible]

1. Upper, the fishing port of N'Gor. A bit of the village is seen at the right. The islet breaks the force of the surf. The nearest boat is perched on skids; the others are recently beached.
Lower, N'Gor village on the dunes. The huts and gardens are typical of all indigenous villages of the Cape Verde Peninsula.

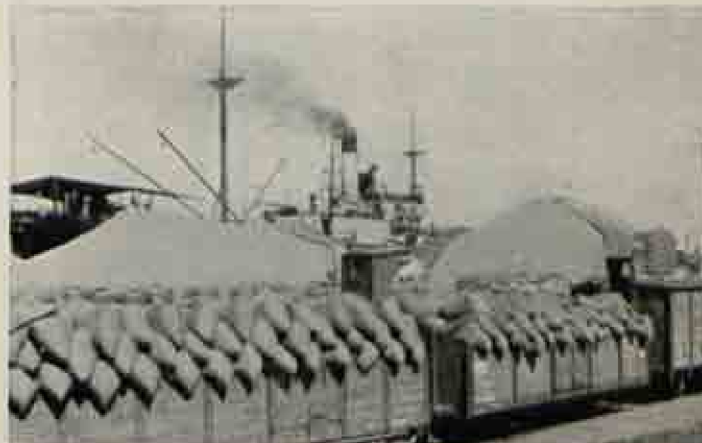
2. Upper, harvest at N'Gor. The women at the left are threshing or grinding millet in a hollow log mortar; those at the right are winnowing beans. The bowls are calabashes. The granaries are perched on logs for protection against rodents.
Lower, Gorée Harbor from near the point. The town is crowded between the cove and the fortified cliff in the background.

1. Upper, a typical residential street in Gorée.
Lower, a principal mole in the commercial harbor of Dakar. The skyline of the city forms the background. The crowd is assembled to greet the liner from which the photograph was taken. The costumes are typical.

2. Upper, fenced African habitations of the sort still common in Dakar proper. The tile-roofed house is of frame construction. The thatched hut is of wattle. The site is half a block from the cathedral.
Lower, Dakar cathedral, under construction. No machinery is employed. The gentleman with the umbrella is in full-dress native costume.

1. Upper, Bernard Cove and Dakar Point (right background). Salt-water intake in the foreground. The prominent buildings on the cliff are a hotel for government officials and the governor's mansion. (Photograph by E. Lattes, Bamako, AOF.)
Lower, the Dakar District Government and the courts are housed in these buildings, in the colonial style of the nineteenth century. They face the Central Plaza. (Photograph by Lataque.)

2. Upper, public buildings facing the street marking the original shore line of the harbor. The overhanging upper stories shade the sidewalks. The flat terrain in the foreground is made land. (Photograph by E. Lattes.)
Lower, the Chamber of Commerce, also facing the Central Plaza (lower left). It was moved from Gorée, and its quarters have been built since the first World War. (Photograph by E. Lattes.)



1. Upper, the public market in the old quarter. Wires throughout the town have been put underground since this picture was taken. The costumes represent several of the many modes to be seen. (Photograph by E. Lalire.)
Lower, the public market at Medina. Goods are displayed in the open or under improvised shelters.

2. Upper, a view northeast across the original plat of Dakar. In the foreground a warehouse; beyond it houses of the better class; at right the leading hotel; in the background the harbor and the Bight of Gorée.
Lower, peanuts in bags and in bulk awaiting shipment at Dakar Harbor. The vessel is a typical freighter of a Marseilles company.

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